1152 Issued April 19, 1909.

U. S. DEPARTMENT OF AGRICULTURE.
OFFICE OF EXPERIMENT STATIONS—BULLETIN 210.
A. C. TRUE, Director.

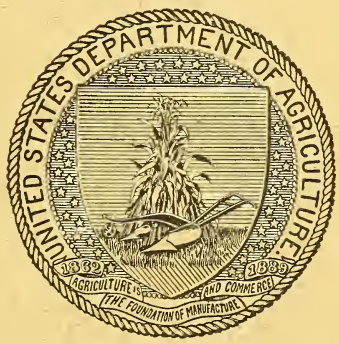
IRRIGATION IN SOUTH DAKOTA.

BY

SAMUEL H. LEA,
State Engineer.

UNDER THE DIRECTION OF

SAMUEL FORTIER,
Chief of Irrigation Investigations.



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LIST OF PUBLICATIONS OF THE OFFICE OF EXPERIMENT STATIONS ON IRRIGATION.

NOTE.—Publications marked with an asterisk (*) are not available for distribution.

BULLETINS.

*Bul. 36. Notes on Irrigation in Connecticut and New Jersey. By C. S. Phelps and E. B. Voorhees. Pp. 64.
*Bul. 58. Water Rights on the Missouri River and its Tributaries. By Elwood Mead. Pp. 80.
*Bul. 60. Abstract of Laws for Acquiring Titles to Water from the Missouri River and its Tributaries, with the Legal Forms in Use. Compiled by Elwood Mead. Pp. 77.
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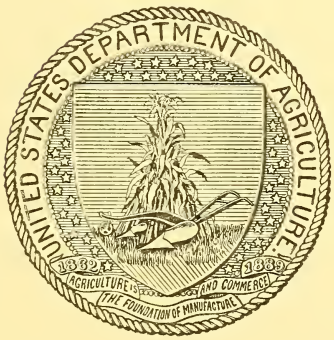

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OFFICE OF EXPERIMENT STATIONS.

A. C. True, Director.
E. W. Allen, Assistant Director.

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Samuel Fortier, Chief.
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[Bull. 210]

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., January 18, 1908.

Sir: I have the honor to transmit herewith a report on irrigation in South Dakota, prepared by Samuel H. Lea, State engineer, under the direction of Samuel Fortier, chief of irrigation investigations of this Office. This is one of a series of reports on irrigation in the arid States and Territories prepared to meet the demand upon the Office for information as to the opportunities for settlement on irrigated lands and the conditions which settlers will meet in taking up these lands. It is recommended that it be published as a bulletin of this Office.

Respectfully,

A. C. True,
Director.

Hon. James Wilson,
Secretary of Agriculture.

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IRRIGATION IN SOUTH DAKOTA.

INTRODUCTION.

South Dakota is situated midway between the Atlantic and Pacific oceans east and west and Hudson Bay and the Gulf of Mexico to the north and south. It covers an area of 76,620 square miles, extending about 370 miles from east to west and about 207 miles from north to south. (Pl. I.)

The State is divided into two nearly equal parts by the Missouri River, which enters near the middle of the northern boundary and flows south and then southeasterly through the State to the southern line; thence eastwardly, forming the southern boundary of the State for more than 100 miles to the southeast corner, where it is joined by the Big Sioux River.

The State presents great extremes of altitude and great variations in topography. At Big Stone Lake, in the northeastern part, the altitude is 967 feet, while at Harney Peak, in the southwestern part, it is 8,700 feet. The greater portion of the State comprises open prairie and table-lands, with surfaces nearly level or gently undulating, varied at intervals by narrow stream valleys. West of the Missouri River the physical features show some marked variations. In the southwestern corner of the State are the Black Hills, covering an area of about 5,000 square miles. These vary in altitude from 3,000 to 5,000 feet, with an extreme altitude of 8,700 feet at Harney Peak. The table-lands, which occupy most of the region west of the Missouri River except the Black Hills, correspond approximately to the original surface before the stream valleys had been eroded. These lands are generally flat or gently undulating, with occasional evidences of higher strata which stand out above the general surface in the form of buttes and ridges.

In the west central portion of the State are the famous Bad Lands, the most notable of which lie southeast of the Black Hills, between Cheyenne and White rivers. This region comprises an area of badly eroded land, cut by deep ravines bordered by high bluffs of clay. The land is for the most part unsuitable for cultivation, and there is very little vegetation over the greater part of the surface.

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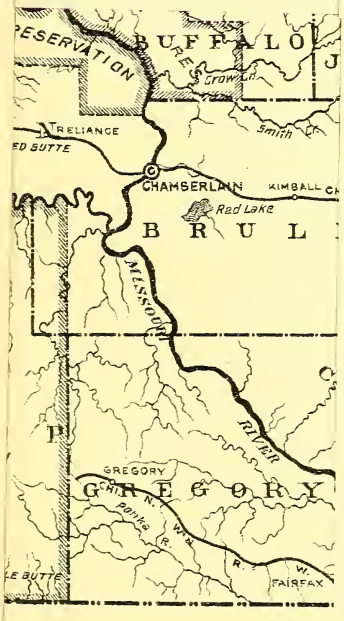
There are no mountains in the State except the Black Hills. In the eastern portion the most extensive elevations are small, isolated areas of high ground designated as "coteaus," which differ from the surrounding country only in greater elevation and in their undulating surface. West of the Missouri River are the buttes, some of which form prominent landmarks, standing out in striking contrast with the surrounding prairie.

The principal industries of South Dakota are agriculture and stock raising. In the eastern part corn, wheat, and forage crops are grown, the general occupation of the people being mixed farming. Wheat growing is the most important industry and is pursued with profit in this section. Corn growing is becoming a prominent factor in the agricultural development, and the corn belt now includes practically the entire east half of the State. The live-stock industry, however, greatly exceeds any other in importance. In the eastern part many hogs and cattle are raised, and much of the farming consists of forage crops and winter feed for cattle. West of the Missouri River, outside of the Black Hills, the principal industry is raising horses, cattle, and sheep, with cattle largely predominating. In some parts of the range large herds of cattle are turned out in the spring and are not seen until the round-up in the fall. In most parts of the range, however, riders keep with the cattle or large pastures are fenced in. Recently much of the public land in Stanley and Lyman counties and near the Black Hills has been taken by homesteaders and the free range is more restricted than formerly.

Mining in the State is confined to the highly mineralized region of the Black Hills, where it is the principal industry, and all others of lesser importance depend upon it for their existence. The present annual product is about $10,000,000, of which 90 per cent is gold. The Homestake mine at Lead, said to be the largest gold mine in the world, has a steady output of $5,000,000 to $6,000,000 per annum.

Little manufacturing is done in the State. Such manufacturing industries as have been established serve principally to supply local demands. The most important exceptions are flour, cement, and milk products, which are shipped out of the State. There is a vast supply of cement material in the bluffs of the Missouri River at Pierre, Yankton, and other localities. A fine quality of Portland cement is manufactured in Yankton. This cement has been used in large quantities by the United States Reclamation Service in the construction of the Belle Fourche project. It is being used in the new South Dakota capitol at Pierre.

The State census of 1905 gives South Dakota a population of 455,185. Since the opening of Lyman and Stanley counties to settlement and the construction of three new lines of railway across the



S

R IRRIGATION.

MAP OF SOUTH DAKOTA, SHOWING STREAMS AVAILABLE FOR IRRIGATION.

western part of the State there has been a large influx of new settlers, and the population is considerably in excess of these figures at the present time.

The public highways are fairly good, although there is room for much improvement. In the eastern part of the State the roads follow the section lines, as they also do nominally in the more thinly settled regions to the west. The Office of Public Roads of the United States Department of Agriculture states that in 1904 there were 59,295 miles of public roads in the State of South Dakota. Of this mileage 147 miles were surfaced with gravel and 4 miles with stone, making 151 miles of improved roads. Comparing the total road mileage with the area of the State, there was about 0.7 mile of public road per square mile of area. A comparison of mileage with population shows 1 mile of road to about every seven inhabitants.

The State is noted for its invigorating climate with high percentage of sunshine. The mean annual temperature is about 45° F., the range being from 100° above zero during the hottest days of summer to 20° below for the coldest days in winter. The air is dry in winter, and a low temperature is endured with but little suffering. From the reports of the United States Weather Bureau, the following summary of mean annual temperatures has been taken:

Mean annual temperatures.

	° F.		° F.
Ashcroft	44	Oelrichs	46
Aberdeen	42	Pierre	47
Bowdle	42	Redfield	43
Gary	43	Rosebud	46
Huron	44	Rapid City	46
Brookings	43	Spearfish	46
Milbank	43	Sioux Falls	44

According to the same authority the average annual precipitation is about 20.3 inches. Of this amount 1 to 2 inches occur during the winter, 6 to 7 inches during the spring, 8 to 9 inches during the summer, and 3 to 4 inches during the fall. Between 15 and 16 inches, or about three-fourths of the annual rainfall, occur from March to August, inclusive. As a rule, the largest amount occurs in the lower James River and Sioux River valleys, and the smallest, it is thought, over the north central and extreme northwestern portions of the State.

During the seeding and growing season the average precipitation, except west of the Missouri River, compares favorably with that of northwestern Iowa and western Minnesota, though the rains, particularly in July and August, are liable to be more local in character than in those States. During March and April, and sometimes in

September, the rains may be steady for a day or two at a time. During summer the rains are of short duration and are followed closely by clear weather, and they occur oftenest in the late afternoon or in the night.

Because of the increasing capacity of the cultivated areas to resist the effects of dry weather there is a growing opinion entertained by some persons who have not closely studied the climatic conditions that the rainfall is increasing. This supposition does not appear to be borne out by facts, and it is highly probable that there has been neither increase nor decrease, to any material extent, in the average amount of precipitation in the State since its settlement.

The annual precipitation in the Black Hills for the past twelve years, as given in the records of the U. S. Weather Bureau, ranges from 16.34 inches at Rapid City to 22.02 inches at Spearfish. This rainfall, in conjunction with a proper application of water by irrigation, will produce excellent crops in this region, as has been demonstrated by experience.

The first killing frost in the fall may be expected in the northern part of the State between September 10 and 20, and in the southern portion between September 10 and 30. The last killing frost in spring may be expected in all parts of the State as late as May 10–20. In the year 1907 there was a frost on August 20, which injured corn in the northern section of the State. The effect of unusually late frosts in the spring is generally to injure fruit and delay seeding and planting operations.

WATER RESOURCES.

The extent to which the public waters are used for beneficial purposes is not great at present, but rapid progress is being made in this direction.

There are several modes of beneficial use of the water supply of the State which may be classified in the order of importance, as follows: Irrigation, power, mining, domestic supply, and navigation.

The use of water for irrigating is confined principally to the western portion of the State, where a considerable area has already been reclaimed and much private as well as Government reclamation is going on.

The development of water power is attracting considerable attention in the State, there being many localities where streams may be utilized for power. At Sioux Falls a large water-power installation is being made to utilize the falls of the Big Sioux River for furnishing light and power in the city. The largest development, however, is in the Black Hills, where the mountain streams have a steady

flow and a rapid descent. Several plants have been constructed for developing water power in this region, and new plants are projected.

There are a number of mines and ore-reduction plants in the Black Hills which require considerable volumes of water. The great Homestake mine at Lead, with its various mills and ore washers, requires an immense quantity of water to carry on its operations. The water supply for this mine and also for the city of Lead is pumped from Spearfish Creek. In much of the western part of the State the natural fall of running streams is sufficient to afford pressure for the domestic water supply of near-by towns.

In the Black Hills, where most of the water-power development has taken place, the power plants are located on the upper reaches of the streams, where the channels descend rapidly, affording opportunities for obtaining a good power head. Such locations are usually above the region of irrigation activity, and the water is returned to the stream channel and can be used for irrigation in the valley below.

The only navigable stream in South Dakota is the Missouri River. This river was utilized for navigation at an early period and had considerable steamboat traffic. In recent years navigation has almost ceased, owing to railroad competition.

RIVER SYSTEMS.

The entire State, with the exception of a small area in the northeast corner, which is in the watershed of the Minnesota River, is drained by the Missouri River and its tributaries.

The streams in the eastern half of the State flow from north to south and those in the western half from west to east. The larger streams discharge considerable volumes of water throughout the year, increasing to vast proportions in the spring and in times of extensive and long-continued rain storms. The small water courses throughout the State are usually dry and serve mainly as channels for storm waters and the melting snows of spring.

The Missouri River flows a distance of 547 miles in the State and falls about 470 feet, making an average fall of 10.5 inches per mile. It flows through a narrow valley less than 3 miles wide between high bluffs. The flood plain is usually about 2 miles wide, but in places narrows down to about a mile. At high water, when the ice breaks up in the spring and during the flood season in the latter half of June and the first part of July, it fills a channel 0.5 mile to 2 miles wide. The water generally carries a quantity of silt and fine sand in suspension, causing it to have a yellowish color. When settled and filtered, however, it is the purest and most healthful water to be found in the State. The water supply for the city of Pierre, taken from wells sunk in the gravel beds adjacent to the river channel, is noted

for its purity. One interesting feature of the Missouri River is the great bend midway between Chamberlain and Pierre. The distance around the bend is 25 miles and the distance across the narrow neck is 1.75 miles. The neck of the peninsula is a bluff of considerable height and the bed of the river is a hard formation furnishing a promising site for water-power development.

James River, the next in importance, rises in the central part of North Dakota and flows south, bisecting that part of the State lying east of the Missouri. It is a sluggish, tortuous stream 80 to 100 feet wide in ordinary stages and 3 to 10 feet deep. It flows through a broad, fertile valley and has a length within the State of about 500 miles, its total length being about 800 miles. It carries an unusually small volume of water for so long a river, and during very dry periods is dry in places as far south as Mitchell.

The Big Sioux River is next to the largest of the three eastern tributaries of the Missouri. It is 336 miles long and its watershed, extending eastwardly into Minnesota and Iowa, covers an area of 8,420 square miles. For the first 70 miles the river is shallow and sluggish, flowing through meadow lands, with a fall of 5 feet to the mile. The country traversed is a region of lakes, many of which are connected with the river by narrow channels. In the lower part of its course the river flows between steep banks, and its bed is rocky, with numerous riffles and falls. The stream is subject to freshets, which have been the cause of much damage by the flooding of adjacent farm lands and other property. The water power of the river has been extensively developed, but, owing to the intermittent nature of its flow, has not been operated with much profit.

The Vermilion River flows between the James and Big Sioux and resembles the latter stream in general character. The two forks rise in Kingsbury County, flow south in parallel lines about 12 miles apart, and unite at Parker. At Vermilion it unites with the Missouri, flowing a distance of 7 miles through the old bed abandoned by the Missouri River in 1881.

The rivers west of the Missouri which flow throughout the year are the Grand, Owl, Cheyenne, and White. These streams have similar characteristics. They flow considerably below the adjacent country, through narrow valleys with high, broad terraces. The valleys and gulches of the tributaries contain considerable small timber, such as cottonwood, box-elder, ash, elm, and cedar. The flow of water in these streams fluctuates greatly according to the season of the year. Their fall is from about 3,500 feet along the west end of the State outside of the Black Hills to the level of the Missouri, amounting to nearly 2,000 feet. The length of the Cheyenne River within the State is about 500 miles and that of the other three streams about 400 miles,

consequently their currents are swift and rapids are frequent. The Cheyenne and its northern branch, the Belle Fourche, almost completely surround the Black Hills.

Some of the smaller streams draining considerable areas are the Teton, or Bad River, between the White and the Cheyenne; the South Fork of the White River in the Rosebud and Pine Ridge Indian reservations; the Keya Paha in the Rosebud Reservation; and the Little Missouri, cutting off a small section in the northwest corner of the State. These streams are dry in places in summer, but at some seasons they carry immense volumes of water.

The precipitation in the Black Hills is greater than in the surrounding country, and the streams rising in them, among which are Fall and Red Water rivers, and Whitewood, Bear Butte, Alkali, Elk, Box Elder, Rapid, Spring, Battle, and French creeks, as a rule have a constant flow, affording good opportunities for water-power development in their upper reaches and for irrigation lower down.

STREAM MEASUREMENT.

No systematic measurement of the flow of the streams of the State has yet been undertaken, although most of the principal streams have been gauged under the direction of the United States Geological Survey. The results of these measurements have been abstracted from the publications of the United States Geological Survey and are summarized as follows:

Discharge measurements of streams in South Dakota.

Date of measurement.	Stream.	Locality.	Discharge.
			Cubic feet per second.
July 17, 1900	Big Sioux River	Watertown	5.0
July 18, 1900	do	do	10.0
Nov. 12, 1900	do	do	7.0
July 21, 1900	do	Sioux Falls	78.0
May 24, 1902	do	Watertown	22.0
July 15, 1902	do	do	2.3
Nov. 15, 1902	do	do	2.7
Apr. 18, 1903	do	do	28.0
May 31, 1903	do	do	23.0
Oct. 17, 1903	do	do	34.0
May 26, 1906	Belle Fourche River	Belle Fourche	573.0
June 22, 1906	do	do	97.0
July 21, 1906	do	do	212.0
Aug. 1, 1906	do	do	928.0
Aug. 30, 1906	do	do	4,072.0
Oct. 28, 1906	do	do	79.0
Mar. 19, 1904	do	do	596.0
Apr. 12, 1904	do	do	166.0
May 21, 1904	do	do	165.0
June 3, 1904	do	do	2,314.0
June 5, 1904	do	do	5,444.0
July 1, 1904	do	do	324.0
Aug. 17, 1904	do	do	26.0
Aug. 30, 1904	do	do	62.0
Apr. 11, 1906	do	do	493.0
Apr. 26, 1906	do	do	236.0
May 19, 1906	do	do	398.0
May 26, 1906	do	do	4,360.0

Discharge measurements of streams in South Dakota—Continued.

Date of measurement.	Stream.	Locality.	Discharge.
			Cubic feet per second.
June 11, 1906	Belle Fourche River	Belle Fourche	886.0
July 24, 1906	do	do	117.0
Sept. 27, 1906	do	do	242.0
May 14, 1900	Cheyenne River	Edgemont	14.6
May 29, 1900	do	do	.5
June 12, 1900	do	do	.7
June 19, 1903	do	do	48.0
Aug. 24, 1903	do	do	42.0
Sept. 21, 1903	do	do	95.0
Nov. 14, 1903	do	do	12.0
Apr. 15, 1904	do	do	21.0
May 14, 1904	do	do	36.0
May 26, 1904	do	do	746.0
June 18, 1904	do	do	526.0
Aug. 6, 1904	do	do	1.0
Sept. 16, 1904	do	do	3.4
Apr. 18, 1904	do	Mouth of Fall River	70.0
Apr. 30, 1904	do	Creston	56.0
Aug. 9, 1904	do	do	48.0
June 17, 1905	do	Edgemont	2,752.0
June 18, 1905	do	do	9,175.0
June 19, 1905	do	do	1,850.0
July 1, 1905	do	do	345.0
July 2, 1905	do	do	8,665.0
July 3, 1905	do	do	3,460.0
July 19, 1905	do	do	75.0
July 20, 1906	do	do	6,280.0
July 28, 1906	do	do	3,730.0
July 29, 1906	do	do	10,960.0
Aug. 5, 1906	do	do	562.0
Aug. 6, 1906	do	do	6,842.0
Aug. 7, 1906	do	do	1,420.0
Aug. 12, 1906	do	do	7,420.0
Aug. 13, 1906	do	do	3,460.0
Mar. 29, 1906	do	do	1,670.0
May 5, 1906	do	do	555.0
May 28, 1906	do	do	1,920.0
May 29, 1906	do	do	2,440.0
May 31, 1906	do	do	927.0
Sept. 5, 1906	do	do	25.0
June 6, 1904	Grand River	Seim	441.0
July 14, 1904	do	do	4.5
June 17, 1905	do	do	514.0
June 19, 1905	do	do	1,368.0
July 1, 1905	do	do	70.0
July 4, 1905	do	do	514.0
July 19, 1905	do	do	156.0
July 28, 1905	do	do	53.0
July 31, 1905	do	do	53.0
Aug. 11, 1905	do	do	16.0
April 22, 1906	do	do	20.0
June 17, 1906	do	do	109.0
June 18, 1906	do	do	2,910.0
June 30, 1906	do	do	89.0
July 21, 1906	do	do	1.0
Aug. 11, 1906	do	do	270.0
Sept. 10, 1906	do	do	16.0
Oct. 7, 1906	do	do	3.0
Sept. 2, 1903	Little Missouri	Camp Crook	380.0
Nov. 11, 1903	do	do	36.0
Apr. 10, 1904	do	do	262.0
May 10, 1904	do	do	54.0
July 7, 1904	do	do	62.0
Sept. 6, 1904	do	do	609.0
Sept. 7, 1904	do	do	321.0
Oct. 26, 1904	do	do	13.0
Apr. 14, 1906	do	do	432.0
Apr. 15, 1906	do	do	57.0
Nov. 14, 1906	do	do	9.2
June 4, 1904	Owl River	Bixby	631.0
June 7, 1904	do	do	771.0
June 8, 1904	do	do	10.0
July 30, 1904	do	do	0.0
Aug. 31, 1904	do	do	0.0
Sept. 2, 1904	do	do	818.0
Sept. 12, 1904	do	do	184.0
Sept. 15, 1904	do	do	0.0
Nov. 26, 1904	do	do	0.0

Discharge measurements of streams in South Dakota—Continued.

Date of measurement.	Stream.	Locality.	Discharge.
			Cubic feet per second.
June 17, 1905	Owl River	Bixby	378.0
June 20, 1905	do	do	1,122.0
July 1, 1905	do	do	30.0
July 4, 1905	do	do	1,122.0
July 28, 1905	do	do	142.0
Aug. 5, 1905	do	do	10.0
Aug. 12, 1905	do	do	4.0
June 24, 1904	White River	Interior	79.0
Aug. 11, 1904	do	do	9.5
Sept. 21, 1904	do	do	4.7
Apr. 4, 1906	do	do	335.0
May 24, 1906	do	do	192.0
Aug. 30, 1906	do	do	483.0
May 13, 1903	Red Water River	Crow Creek	80.6
Mar. 22, 1904	do	Belle Fourche	188.0
Apr. 13, 1904	do	do	224.0
May 13, 1904	do	do	113.0
June 3, 1904	do	do	447.0
June 5, 1904	do	do	7,000.0
June 10, 1904	do	do	1,472.0
June 13, 1904	do	do	726.0
June 30, 1904	do	do	297.0
July 20, 1904	do	do	165.0
Mar. 26, 1906	do	do	1,190.0
Apr. 28, 1906	do	do	198.0
May 24, 1900	Rapid Creek	5.5 miles above Rapid City	48.8
June 8, 1900	do	do	26.3
May 25, 1900	do	Rapid City	64.2
June 8, 1900	do	do	29.9
June 10, 1903	do	do	170.0
Aug. 18, 1903	do	do	46.0
Sept. 17, 1903	do	do	91.0
Nov. 4, 1903	do	do	58.0
Mar. 26, 1904	do	do	53.0
Apr. 23, 1904	do	do	141.0
May 18, 1904	do	do	127.0
June 7, 1904	do	do	665.0
June 21, 1904	do	do	433.0
Aug. 8, 1904	do	do	91.0
Sept. 17, 1904	do	do	89.0
Mar. 31, 1906	do	do	109.0
Apr. 6, 1906	do	do	76.0
May 8, 1906	do	do	88.0
May 26, 1906	do	do	241.0
Sept. 1, 1906	do	do	66.0
June 27, 1903	Box Elder Creek	Black Hawk	39.0
Aug. 21, 1903	do	do	3.4
Nov. 6, 1903	do	do	.4
June 7, 1904	do	do	377.0
June 26, 1904	do	do	91.0
Aug. 15, 1904	do	do	4.5
Sept. 24, 1904	do	do	4.7
May 14, 1903	Spearfish Creek	Near Spearfish	106.0
May 27, 1903	do	do	61.0
Aug. 14, 1903	do	do	38.0
Sept. 22, 1903	do	do	71.0
Mar. 30, 1904	do	do	72.0
Apr. 25, 1904	do	do	128.0
May 25, 1904	do	do	149.0
June 17, 1904	do	do	291.0
Aug. 3, 1904	do	do	90.0
Sept. 15, 1904	do	do	80.0
Mar. 27, 1906	do	do	87.0
May 2, 1906	do	do	119.0
June 3, 1906	do	do	136.0
Sept. 2, 1906	do	do	65.0

APPROPRIATED AND UNAPPROPRIATED WATERS.

SPEARFISH CREEK.

Of the streams in western South Dakota the one along which irrigation has been carried on most extensively is Spearfish Creek, which originates in two big springs near the southern boundary of Lawrence County and flows northward and is augmented by a few tributaries, Little Spearfish Creek being the largest. This stream is fairly uniform in its flow, the fluctuations at different seasons being remarkably small. It has a fall throughout most of its length of about 100 feet to the mile, which gradually lessens toward the lower end of the valley, where the average fall is about 60 feet.

The information given here is taken from the Report of Irrigation Investigations for 1902.[a] The average or normal flow of Spearfish Creek is about 50 cubic feet per second. There are twelve ditches taking water out of the creek for irrigation purposes, besides five for power. The irrigation ditches have a total capacity of 91.5 cubic feet of water per second and irrigate 4,810 acres. In addition there are three other ditches which are supplied from one of three tributaries of Spearfish Creek. These have a combined capacity of 10.3 cubic feet per second and irrigate 525 acres. It is seen that the total volume of water carried by the ditches is about twice the normal flow of the stream. The total area is 5,335 acres, which is irrigated with 101.8 cubic feet per second of water, or at the rate of 1 cubic foot per second for 52.4 acres. This acreage can be greatly increased by a careful use of the supply with proper precautions taken to prevent waste. A measurement of the creek at its mouth and below all the ditches shows a flow of 29 cubic feet per second. This shows to what an extent seepage from the upper ditches returns the water to the stream, thus allowing the water to be used a second time in its course through the irrigable district and accounts for the apparent discrepancy above.

REDWATER RIVER.

In the Redwater Valley below the mouth of Spearfish Creek, irrigation is practiced on ranches devoted to raising hay for feeding live stock. Lower down the Redwater Valley and extending over to the Belle Fourche Valley is the largest private irrigation system in the Black Hills region, viz, the Redwater Canal. This ditch has a measured flow of 41 to 71 cubic feet per second. The head gate is about 5 miles above the mouth of Redwater River. The entire length of the canal is about 42 miles, but the lower 12 miles has been abandoned, leaving 30 miles in use. About 10,000 acres are capable of being irrigated, though only about 5,000 acres are now irrigated.

[a] U. S. Dept. Agr., Office Expt. Stas. Bul. 133.

FALL RIVER.

Fall River Valley in its upper portion near the city of Hot Springs is divided into small tracts which are devoted to fruits and market gardens. Fall River is fed by many warm springs and the water keeps warm throughout the year, not freezing even in winter. Only a small portion of the land susceptible of irrigation is under cultivation. The normal flow of Fall River is about 32 cubic feet per second. This is sufficient to irrigate over 2,000 acres if the water is carefully used.

CASCADE CREEK.

Cascade Creek is a small stream rising about 10 miles southwest of Hot Springs and emptying into the Cheyenne River. It is fed by warm springs and has a steady flow of about 28 cubic feet per second. The valley lands along Cascade Creek and for some distance below its mouth on the Cheyenne River have been brought under cultivation by irrigation from this stream. About 2,000 acres are now being irrigated, which is about the capacity of the stream.

RAPID CREEK.

The irrigable portion of Rapid Creek Valley begins about 6 miles above Rapid City, where the stream emerges from the hills. Below this point the creek runs through a valley from 1 to 2 miles wide for a distance of about 36 miles to its junction with the Cheyenne River. This entire valley is practically under irrigation, eight or more ditches being in operation. During the irrigation season there is a scarcity of water, but during the spring floods there is a large surplus of water in this stream, and the construction of reservoirs for water storage would enable water users to irrigate a large additional area of land. There are several natural basins along the valley favorably situated for use as storage reservoirs. Rapid Creek above Rapid City is especially valuable for water power. The city electric-light plant and a flour mill are now run by the stream, and there are several large power plants projected farther up. Permits have been obtained from the State engineer for the use of the water for power purposes, and their combined capacity will aggregate several thousand horsepower.

BEAVER CREEK.

This stream carries a large flow during the spring and early summer, but runs nearly dry later in the season. Beaver Creek offers an excellent example of the need and opportunity for a system of storage for conserving flood waters. The valley is about 10 miles long and gradually widens to 5 or 6 miles at the lower end. There are at present six irrigation ditches in use, but only three are of importance,

as the water supply is not sufficient for all. With a proper method of storage the flood waters which go to waste every spring could be saved and sufficient water utilized to irrigate 10,000 acres, in addition to the land now under ditch. There are several excellent sites along the valley which can be utilized for storage reservoirs.

OTHER SMALL STREAMS.

The following creeks are capable of being utilized for irrigation: False Bottom, Bear Butte, Elk, Alkali, Box Elder, Spring, French, and Battle. These have practically a continuous flow, although like many other streams in the State, the flow is very small in the dry season. In many cases they pass over sandstone strata in some parts of their course and the water sinks underground. In flood periods, however, the flow is sufficient to pass over the strata and goes the entire length of the channel.

There are several thousand acres of land in these valleys that can be irrigated if the water is prevented from sinking into the ground or if flood storage be practiced. Both of these objects can be accomplished and many profitable farms can be cultivated.

BIG SIOUX RIVER.

This river has been utilized to a considerable extent as a source of power. The stream, however, is subject to great fluctuations in flow. It has been brought to the attention of those interested that improvements in the flow of the river, principally by means of storing flood water to be subsequently used in eking out the low-water flow, would not only prevent the periodic devastation of lands and destruction of property by floods, but incidentally benefit the users of water power by furnishing them more power during the summer and fall months.

This river being a tributary of the Missouri, the interception and storage of its flood waters would be directly in line with the policy of the Government of constructing storage reservoirs at the headwaters of the Mississippi River system.

An examination of the Big Sioux River was made in 1900 by Capt. H. M. Chittenden, with a view to the construction of a dam for the storage of surplus water of this stream in Lake Kampeska and Lake Poinsett. A reconnaissance of the basin comprising Kampeska, Pelican, and Poinsett lakes was made by the officials of the United States Geological Survey with the same object in view. The following information has been taken from the report of the Chief of Engineers of the United States Army for 1901, and from the Twenty-second Annual Report of the United States Geological Survey:

Kampeska and Pelican lakes are 2 miles apart, Lake Kampeska being 3 miles northwest of Watertown. The area of this lake is

given on the county map as 5,000 acres, and it is surrounded by steep banks and high lands, except at the east end, where the banks are not more than 5 feet high. In considering the storage possibilities a height of 4 feet should not be exceeded. The level of Lake Pelican is about 10 feet lower than that of Lake Kampeska, and the surrounding lands are of comparatively little value. The flooding of these lands, therefore, would not entail serious expense. By raising the water level in Lake Kampeska 3 feet above the normal and the level of Lake Pelican 13 feet the storage capacity of 15,000 acre-feet in Lake Kampeska and 40,000 acre-feet in Lake Pelican would be obtained. All of this, deducting losses by evaporation, could be utilized during the summer season to swell the discharge of the Big Sioux River.

Lake Poinsett is situated farther down the stream, and consequently has a larger catchment area than the two upper lakes, and can therefore control a much larger area than either of the two other lakes, and would have sufficient capacity to store a large proportion of the flood waters of the river. Examinations and surveys have been made to determine the practicability of storing flood waters in Lake Poinsett and also to ascertain the area and capacity of the lake. The area of this lake is about 8,250 acres, and a flood height of 7 feet is proposed. The net loss from evaporation and seepage, allowing for the accession from rainfall upon the catchment area, is estimated at 12 inches. This leaves an available storage of 6 feet, equivalent to nearly 50,000 acre-feet. Taking into consideration the ordinary flow of the stream, it is believed that with a reservoir at Lake Poinsett, as described above, the flow of the Big Sioux River could be so controlled as to produce a near approach to uniformity throughout the year, with a minimum flow of 150 cubic feet per second.

The benefits that would accrue from this proposed storage system would be very great. The floods along the Big Sioux River have been destructive of crops and property, especially in recent years, when they have been of frequent occurrence. Such a storage system would at least hold back the crest of the flood wave and thus prevent a large amount of devastation in the valley, especially in that portion immediately below the reservoir.

ARTESIAN WELLS.

A valuable source of water supply in the State is the artesian well system. This has been developed most extensively in the James River Valley, where there are numerous wells in which water has been obtained at depths of 300 to 600 feet. In the counties bordering the Missouri River Valley there are numerous wells whose depths vary

from 800 to 1,700 feet. In many cases a pressure of 100 to 175 pounds is obtained, which, when the flow is large, affords power for milling purposes. The artesian wells in the Missouri River Valley carry a large quantity of natural gas, which is separated from the water by a simple process and is used for heating, lighting, and power. Pierre is within the gas belt and secures from three wells an abundance of gas for generating all power required in the city, as well as for domestic lighting, cooking, and, to a great extent, for heating the city. In Fort Pierre one well provides power for pumping city water and for general power, heat, and light purposes.

In the valley of Bad River the artesian wells produce water at a temperature of 120° to 138° F., and at Edgemont there is a well 2,970 feet deep which produces water at a temperature of 120°. The water from this well is said to be soft and suitable for domestic use.

LANDS.

The greater part of the lands of the State may be classed as arable. From the State census of 1905 the following data have been taken relative to land areas in South Dakota: Total acreage of farm lands, exclusive of 1,352 farms on Indian reservations, 16,442,323 acres, of which 7,429,976 acres is plowed land, 3,041,185 acres hay land, and 5,971,162 acres pasture land. The farm lands on the Indian reservations comprise 2,120,417 acres. Within the last three years a very large area of public land has been taken up in homesteads in Stanley, Lyman, Butte, and Pennington counties, west of the Missouri River. There are no data available showing to what extent this land has been put under cultivation.

There is over 3,000,000 acres of school and endowment lands owned by the State in trust for the maintenance of schools and charitable institutions. These are practically all unsalable lands, about 20 per cent being grazing land and the remainder suitable for cultivation. The law authorizes the State commissioner of school and public lands to offer for sale 50,000 acres of these lands each year. In addition, there is about 50,000 acres of capitol building lands, which are to be sold and the proceeds applied to the construction of a State capitol building.

FORESTS.

The forest areas of South Dakota are situated principally in the Black Hills, although there are isolated tracts of timbered land among the buttes or hills found in the northern part of Butte County. The Cave Hills are near the northwest corner of the State, and southwest of these are the Short Pine Hills, consisting of two nearly parallel ranges 4 to 6 miles long, running north and south. The Slim

Buttes, situated near the center of the county, form an L-shaped ridge, extending 25 or 30 miles, with a breadth of 0.5 to 3 miles. These hills are more or less supplied with timber, the red pine growing abundantly in the ravines and on the slopes and showing above the summit plains.

Outside of this region the most important timber lands occur on the bottom lands in the bends of the Missouri River and on the islands in that stream. Single tracts of timber rarely exceed 1,000 acres, although a few much larger tracts occur near the southeast corner of the State, but these are rapidly disappearing. Cottonwood, elm, cedar, butternut, and ash are the most common varieties. The National Forest Reserves in the State, as defined in bulletins of the U. S. Forest Service, consist of the Black Hills National Forest and the Sioux National Forest. The former comprises 1,163,160 acres, situated in the Black Hills region. The latter is a consolidation of the three small forest areas as follows: Cave Hills, having an area of 23,360 acres; Short Pine, 19,040 acres; and Slim Buttes, 58,160 acres; total area, 100,560 acres. The two National Forests contain in the aggregate 1,263,720 acres.

WASTE LAND.

The waste lands of the State comprise essentially the famous Bad Lands in the western part and the marshes and overflowed areas in the eastern part. There are also areas in the higher parts of the Black Hills that may be classed as waste or nonproductive lands. In the extreme eastern part of the State are numerous lakes and lake beds, varying in size from small ponds to miles in length. After a series of rainy seasons these are filled, and some of them continue to hold water for years afterwards. In the vicinity of these lakes and in the flat country adjacent to the river valleys are large areas requiring drainage in some years. It is estimated that the lands requiring drainage and which are either overflowed periodically or are normally wet comprise an area of about 300,000 acres. A large portion of this area was considered sufficiently dry to be cultivated without drainage during a considerable period designated as the dry years. For several years, however, the spring floods in the Big Sioux, James, and Vermilion rivers have occurred with annual regularity and have demonstrated the necessity of the drainage of large areas of land. The land thus involved comprises some of the most fertile soil in the State, and in most cases the crop destroyed by one flood would be of more value than the cost of adequate drainage works.

A great deal of drainage work is being done in this section with the object of reclaiming the lands. Surveys have been made under

the direction of the State engineer, and plans have been made by him for the reclamation by drainage of the Big Sioux Valley immediately above the city of Sioux Falls, the area involved comprising about 12,000 acres of rich farming land. Other large drainage projects are under way in Clay, Union, and other counties in the southeastern part of the State.

THE BAD LANDS.

The Bad Lands of western South Dakota have attained a world-wide notoriety. The most notable area coming under this designation lies between the Cheyenne and White rivers, southeast of the Black Hills. This region is badly cut up by ravines, and is bounded largely by continuous high clay bluffs. The following description of this strange formation is taken from a bulletin of the South Dakota geological survey:[a]

> One approaching the Bad Lands may gradually ascend a rolling, grassy surface until he suddenly comes to the crest of a ridge and finds himself gazing from a height of 200 to 400 feet upon a labyrinth of winding ravines and narrow ridges, which in some places widen into broad buttes capped with tables formed by harder strata, or surmounted with slender pinnacles, reminding one of the spires of a cathedral; at other points the harder beds stand out as cornices and buttresses around the more prominent buttes. While this may appear near by, farther away he may see graceful, rounded domes and ridges, which remind one of haystacks and railroad embankments, where they continue as narrow ridges with their tops extending upon the same level for some distance.

Similar areas of much smaller extent are found along the Cheyenne and Missouri rivers, eroded from the lead-colored cretaceous clays. The Bad Lands in western South Dakota comprise an area of 2,000 square miles, most of which can not be utilized for agricultural purposes.

HILLS AND BUTTES.

The only mountains in the State are the so-called Black Hills, in which region occur extensive areas almost destitute of soils, and ledges of exposed rock. In the higher portions of the hills region there are numerous natural parks with a soil consisting of sandy and gravelly loam, but the area for the most part is gravelly and stony, with just enough soil to support the pine-forest growth which covers a great portion of the Black Hills region. The river deposits, which in some cases are quite deep in the bottoms of the narrow valleys and canyons, are similar to like deposits elsewhere, except that they are unusually sandy and gravelly.

In the eastern part of the State are the east and west coteaus, table-lands, which differ from the surrounding country only in their

[a] South Dakota Geol. Survey Bul. 1, p. 103.

greater elevation. There are a number of other coteaus in this region that attract attention more on account of their isolation than on account of any other remarkable feature.

In the western part of the State, Thunder Butte, near the northwest corner of the Cheyenne River Indian Reservation, is a striking feature. Bear Butte, in Meade County, lying outside of the Black Hills area, is, on account of its height, size, and isolation, the most majestic peak of its kind.

GRAZING LANDS.

Until recent years the greater part of the western half of the State was used for grazing purposes. This region constituted for the most part a vast open range where horses, cattle, and sheep were raised. Great herds of cattle roamed the range at will, subsisting on the natural grasses of the prairies and going through the cold and storms of winter as best they could. In some cases the losses of cattle during a severe winter amounted to 10 per cent of the herd. This condition of affairs still prevails to some extent, but the free range is practically a thing of the past. On account of the large influx of settlers into Stanley, Lyman, and Butte counties the free range has been much restricted. More than 5,000 homesteads, comprising over 800,000 acres of land, have been filed upon in this section in the past two years, and there is a steady flow of settlers to these lands. There is still, however, a large extent of valuable land subject to entry in this region.

UNOCCUPIED AREAS.

The principal areas of unoccupied lands suitable for settlement are to be found in Butte County, although there are many thousands of acres of good land still unoccupied in Meade, Pennington, Custer, and Fall River counties. In Stanley and Lyman counties, where two new lines of railways have been constructed recently, considerable settlement has taken place, but there is still a large area open for settlement. In the eastern part of Meade County there is an extensive area still unoccupied. It is remote from market, but is well adapted to settlement. There are several running streams, bordered with timber, and the surface is gently undulating, with a fine growth of native grass. The west-central portion of the State, which is largely occupied by Indian reservations, is well watered by numerous streams. A considerable part of this area is leased by stockmen for grazing purposes. This section when eventually opened for settlement will afford much excellent land for cultivation.

IRRIGATED AREAS.

From the Twelfth Census of the United States and from the data on file in the State engineer's office the following information relative to irrigated areas in South Dakota has been compiled. The area irrigated from streams is confined largely to the territory adjacent to the Black Hills region and comprises the following counties: Butte, Meade, Lawrence, Custer, Pennington, and Fall River. Practically all the area irrigated from streams in the State is supplied from the tributaries of the Cheyenne River which head among the forested slopes of the Black Hills and afford a certain water supply. Important among these are Box Elder, Spring, and Rapid creeks in Pennington and Custer counties, and Beaver Creek and Fall River in Fall River County. The first three mentioned furnish water to more than one-half the area irrigated by private irrigation works in the State. Bear Butte Creek is an important stream which supplies water for most of the irrigated area in Meade County, its full flow being utilized. In Lawrence County an important source of water supply is Spearfish Creek, which is fully appropriated. The most valuable irrigation land in the State is situated on this stream, the prices ranging from $35 to $75 per acre, with the best alfalfa land worth $150 per acre, and some orchard land still more valuable. The following table shows the extent of irrigated area under private works in the State:

Irrigated areas in 1908.

County.	Area irrigated.	Irrigation systems in use.				
		Number.	Length of main ditches.	Cost of construction.		Cost of maintenance per acre.
				Total.	Per acre irrigated.	
	Acres.		*Miles.*			
Butte	7,798	23	46	$121,603	$15.59	$0.20
Meade	2,979	20	24	8,522	2.86	.30
Lawrence	6,687	42	44	27,764	4.15	.20
Pennington	14,891	29	67	61,636	4.14	.19
Custer	5,188	53	43	19,073	3.68	.54
Fall River	4,526	21	22	25,409	5.61	.20
The State	42,069	188	246	264,007	6.00	.27

The above areas are practically all under cultivation and are producing profitable crops. The irrigated land is quite valuable and commands a good price per acre when placed on the market, but owners as a rule do not care to sell. There is, however, a considerable area of unoccupied land in the State that is now under ditch and ready for settlement. Under the Belle Fourche project, now being constructed by the U. S. Reclamation Service, there is about 12,000 acres of good land to which water has been furnished.

Part of this land has been taken up, but there is still available a considerable area, a large part of which is public land that can be secured as homesteads by settlers upon complying with the necessary requirements. The location of this irrigable area is within a few miles of the town of Belle Fourche, in Butte County. This is an excellent opportunity for prospective settlers who wish to obtain good land under ditch at a minimum cost.

CROPS GROWN UNDER IRRIGATION.

The principal agricultural products of irrigated lands are small grains, fruits, vegetables, and alfalfa and native hay. The grain crops include oats, wheat, rye, and barley, all of which yield excellent results under irrigation. The production of forage for feeding cattle constitutes the greatest agricultural industry in the irrigated section. Native hay and alfalfa are grown extensively and always find a ready market at good prices. The demand for farm and garden produce is very large, especially in the mining region. The most profitable results in irrigated products are obtained from the smaller fruit and vegetable farms. The greatest development in this class of farming in South Dakota has taken place in Spearfish Valley, which has become under irrigation a veritable garden spot, its small farms having well-kept homes, thrifty groves, and luxuriant gardens. The prosperous mining centers of Lead and Deadwood, within 30 miles, and the many smaller mining communities throughout the Black Hills, afford excellent markets for all the farmer can produce.

From the Report of Irrigation Investigations for 1902 [a] the following statement is taken:

Yields of products on irrigated farms in Spearfish Valley, South Dakota.

Crop.	Yield per acre.	Approximate price.
Alfalfa (3 cuttings)....tons..	3.5 to 6.....	$9 to $10 per ton.
Timothy and clover (3 cuttings)....do....	3 to 4.....	$10 to $12 per ton.
Wheat (very little raised)....bushels..	25 to 40.....	Market.
Oats (very little raised)....do....	40 to 60.....	Do.
Potatoes....do....	300 to 500.....	$1 to $1.50 per cwt.
Onions....do....	400 to 500.....	Do.
Apples....barrels..	25 to 30.....	$4 per barrel.
Carrots, beets, turnips, etc....tons..	20 to 30.....	
Strawberries....quarts..	3,500 to 5,000....	20 cents per quart.
Raspberries....do....	3,500 to 4,000....	Do.
Blackberries....do....	2,000 to 3,000....	Do.
Dewberries....do....	3,000 to 4,000....	Do.
Gooseberries....do....	3,000 to 4,000....	Do.
Currants....do....	4,000 to 5,000....	Do.

These are the main market crops in this valley, but radishes, asparagus, peas, and beans, and all other garden vegetables are raised in

[a] U. S. Dept. Agr., Office Expt. Stas. Bul. 133.

great profusion. This is a fine showing and goes to indicate that the Black Hills region is a natural home for the small fruits.

No recent statistics showing the acreage, production, and value of crops produced on irrigated land in the State are available. The figures given in the Twelfth United States Census may be of value as showing what was actually produced under irrigation in the year 1899. These data are in tabular form as follows:

Acreage, production, and value of irrigated crops.

Crop.	Area.	Quantity.	Value.
	Acres.		
Hay and forage	20,237	[a] 42,114	$110,285
Cereals	5,949	[b] 146,720	40,674
Vegetables	1,361	.....	41,591
Orchard fruits	847	.....	5,690
Small fruits	54	.....	2,328
Other crops	873	.....	7,497
Total	35,321	.....	208,065

[a] Tons. [b] Bushels.

Since these data were gathered there has been considerable increase in the acreage cultivated and quantity of crops raised, and the values at present are somewhat higher than those given.

HAY.

The growing of alfalfa and other hay crops is an important industry in this section. Different methods of irrigation are followed, but commonly water is applied in the spring as soon as the crop seems to need it, and the soil is watered as soon as each crop except the last is taken off the field. The ground is then left dry to prevent the heaving of the roots and winterkilling. The average yield of the hay crop is about 6 tons per acre, worth about $5 per ton in the stack. The average cost of production is $1.40 per ton in the stack, and the average net returns per acre amount to $21.60.

FRUITS.

The growing of fruit is quite profitable in some localities, especially the Spearfish and Fall River valleys. The orchard of G. M. Trimmer, near the town of Hot Springs, is a good example of fruit culture on irrigated land on a small scale. This orchard is only 5 acres in extent, but in it are raised about 1,000 bushels of apples, besides pears, plums, and cherries. The net profits from this little orchard are stated to be over $1,000 per year, or $200 per acre. The trees are several years old and in full bearing.

VEGETABLES.

The raising of vegetables and small fruits is a profitable industry in Spearfish Valley. The yield, as shown by the tabular statement

previously given, is quite large, and the labor of cultivation is considerable, but the profits vary according to local conditions affecting the markets. The net returns range from $50 to $200 per acre.

With regard to a comparison of irrigated and unirrigated crops, there are some seasons when the amount of rainfall in this section is sufficient to produce fairly good yields, although these are never as large as when irrigation is practiced. For several years past there have been good seasonable rains throughout the State and the yields of unirrigated farms, where approved methods were followed, have been good, even in the dry sections. On a farm comprised of about 200 acres, situated about 5 miles from the town of Belle Fourche, cultivated for the past seven years without irrigation, the average yield of wheat has been 20 bushels per acre; oats, 40 bushels; and barley, 45 bushels. This is above the general average for unirrigated land and is due largely to favorable seasons as well as to dry-farming methods of soil culture.

The Sorenson farm in Butte County, near Snoma, is irrigated by means of a reservoir storing storm water. This constitutes a method of partial irrigation to which reference is made elsewhere in this paper. The yield from the 125 acres thus irrigated was in one year 225 tons of hay, which sold for $2,250. The cost of maintaining the irrigation works was large, and consequently the net returns per acre were considerably smaller than would otherwise have been obtained. In this instance, with partial irrigation, returns of from $10 to $12 an acre were made, where without it no crop would have been raised.

As an indication of the relative values of irrigated and unirrigated lands in the western part of the State the price of land under irrigation in Fall River Valley in 1907 was given as $25 to $75 an acre, while irrigated fruit land in Spearfish Valley was worth as high as $300 an acre. Land not under ditch, but which might be irrigated, was valued at about $10 an acre, while that which was incapable of being irrigated sold at $1.25 to $5 per acre.

FARMING WITHOUT IRRIGATION.

Attempts have been made in several localities to raise crops without irrigation, but it is only once in several years that the conditions are such as to afford satisfactory results. In an exceptionally wet season small crops have been raised in the Centennial Valley, about 10 miles east of Spearfish, and in some of the parks north of Hot Springs. There is no certainty of a crop, however, and many who in earlier days attempted to farm unirrigable farms now use them wholly for grazing purposes.

IRRIGATION DEVELOPMENT.

Owing to its geographical situation and because of local variations in rainfall the conditions affecting irrigation in South Dakota are not the same in all parts of the State.

In the early days of statehood there was a period of dry seasons in the region east of the Missouri River, and public attention was directed to the use of artesian wells for irrigation purposes. The office of State engineer of irrigation was created in the State in 1890, and the duties of the incumbent related almost exclusively to artesian wells. He was required to make general investigations of the artesian water supply of the State and to confer with manufacturers of well-drilling machinery and with transportation companies with a view to securing such machinery at the least possible cost. An important part of his duties consisted in the location and acceptance of artesian wells for township authorities in order to legalize the public construction of such wells and enable the authorities to float bonds for defraying the cost. The abundance of moisture furnished by rainfall during succeeding years and the difficulty of obtaining satisfactory results from artesian irrigation caused the public interest to fall off, and in 1897 the office of engineer of irrigation was abolished and provision made for an instructor in the State Agricultural College to perform such duties as were required of the engineer.

This half of the State has for a number of years been blessed with sufficient rainfall to produce bountiful crops, and there is no recognized need for irrigation. Near the eastern border and in the southwestern part of the State there is, on the other hand, urgent need for adequate drainage systems to carry off the surplus water from spring floods. In the western part of the State, however, the annual precipitation is less and irrigation is required to produce good crops. This is especially the case in the extreme western section adjacent to the Black Hills. Numerous small streams originate in these hills, fed from springs and augmented by the melting of the snow which lodges in the valleys and gulches in the winter. These streams flow through steep and rocky canyons radiating to the north, east, and south until cutting through the foothills each stream spreads out into a fine valley, finally emptying into one of the forks of the Cheyenne River, two of which, the Belle Fourche and South Fork, encircle the hills and separate them from the surrounding prairie. These valleys are all fertile and are very productive when supplied with water, although barren to a large extent and devoid of useful vegetation when not irrigated.

A large proportion of the first settlers in these valleys came from Montana, and being familiar with the use and value of water located

with reference to a water supply, filing their water rights almost as soon as they took out their land claims, many of them as early as 1876 and 1877. This period may be considered the beginning of irrigation in the State. The Black Hills country is the oldest agricultural district in South Dakota except a small section on the eastern border near the Iowa and Minnesota line.

From these beginnings the practice of irrigation progressed slowly until the boom period of the late eighties, when the artesian movement in the eastern part of the State coincided with the irrigation development in the western portion. During this period two important irrigation canals were constructed in the region adjacent to the Black Hills. Others were undertaken and afterwards completed. The most important of these irrigation canals is the Redwater Canal, which has been mentioned already. Another important irrigation canal is the Edgemont, built to irrigate a part of the valley of the Cheyenne River immediately above the town of Edgemont in Fall River County. This canal, which is 14 miles long, was constructed at great expense, but afterwards abandoned upon the failure of the company promoting the enterprise. It has since been repaired and has been in useful operation for several years. A number of irrigation canals were constructed during this period in Rapid Creek Valley below Rapid City in Pennington County. These have practically all been kept up and are to-day performing good service in the way of irrigating that fertile valley.

From time to time, as the country settled up and the needs of individual settlers demanded, the construction of private irrigation works was carried on, but no considerable activity was manifested in this line for a number of years. This was partly due to the fact that land was cheap and that some sort of crop could generally be raised without irrigation, especially in close vicinity of the Black Hills, where the rainfall was greater than in the adjacent region. For several years there has been a good annual rainfall, well distributed through the growing season, which has rendered the necessity for irrigation, at least for ordinary requirements of crops, less pressing. The greater part of this region has been used for grazing purposes by stockmen. These several causes retarded the progress of irrigation in the State, and the impression became quite common that irrigation was more of a luxury than a necessity in any part of the State.

Another factor which entered into the situation is that growing crops by irrigation is very hard work, requiring close attention and much labor to produce the best results. It means the cultivation by intensive methods of small areas, in direct contrast with the old-style "bonanza" farms and the practice of "farming on horseback," to use a local phrase.

The increase in the volume of new settlers and the growing scarcity of land have resulted in a change in methods of cultivation and emphasized the necessity of getting better crop yields from cultivated areas. Increased land values demand better returns from the land, and increase in population calls for larger yields from the fields. The greatest factor, however, in the development of irrigation in the State is the undertaking by the Government of the Belle Fourche irrigation project in Butte County. The beginning of this immense undertaking marked a new era in the progress of irrigation work in South Dakota. The prospect of the addition to the agricultural resources of the State of such a large area of highly productive land, the construction of the great storage reservoir, and the hundreds of miles of ditches to convey the water over the land stimulated the movement for irrigation development and indicated the necessity of an effective State supervision of streams. In addition to this the admission by Federal authority of State ownership of nonnavigable public waters rendered necessary the maintenance by the State of a recognized central authority for their supervision.

The State legislature of 1905 enacted a State irrigation code drawn up on lines recommended by officials of the Reclamation Service. This law authorized the appointment by the governor of a State engineer, who is required to be a technically qualified and experienced engineer. The term of office was fixed at six years, and the duties of the position comprise the general supervision of the waters of the State and of the measurement, appropriation, and distribution thereof. This step placed South Dakota in line with other States in which irrigation is practiced and marks a decided progress toward improved irrigation conditions.

The State engineer's department is now a recognized institution in South Dakota, and the work of administering the new irrigation law is going on steadily. The determination and tabulation of existing water rights, obtained under the old law, has been taken up and certified copies of original filings have been forwarded from the different counties to the State engineer's office for permanent record. The work of surveying the streams of the State is carried on systematically under the personal supervision of the assistant State engineer. A field party has been engaged in this hydrographic survey work for several months, and a complete survey of Rapid Creek from the Cheyenne River to Rapid City has been made. It is intended to carry this work on vigorously as long as funds are available for the purpose. The various streams furnishing water for irrigation, as well as those that can be utilized for water power, will be surveyed in succession, and the results will be made a matter of record by means of maps and field notes.

The State geological survey of South Dakota is working in connection with the State engineer's department by maintaining a field assistant on the hydrographic survey party, and the natural resources of the State are being surveyed and located as rapidly as conditions will permit.

IRRIGATION ENTERPRISES.

The seasonal distribution of the rainfall, the planting of seeds adapted to the local conditions of soil and climate, and improved methods of cultivation have effected a satisfactory condition of agriculture in eastern South Dakota, which admits of the production of excellent crops in ordinary years without artificial application of water to the land. It is not improbable that there will be from time to time a recurrence of dry periods in the future, but on account of the increasing use of scientific methods of soil culture there will be no such disastrous results therefrom as occurred during similar periods in the past.

In the western part of the State there are a number of irrigation systems in use, many of them of considerable importance. The region just west of the Missouri River, comprising the Standing Rock, Cheyenne River, Rosebud, and Pine Ridge Indian reservations, has not yet been opened for settlement and will therefore be left out of the discussion. The remaining portion west of the Missouri is still largely undeveloped, although rapidly settling up, especially in the sections adjacent to the three new lines of railroad extending westward through the State. In this newly settled region there have been no important irrigation works constructed, the attention of the settlers having been directed in this line mainly to the construction of small reservoirs for storing storm water. These reservoirs are used principally as a source of water supply for stock, although in many cases small areas are irrigated from them for raising alfalfa or vegetables and other products for local use.

IRRIGATION SYSTEMS UNDER PRIVATE ENTERPRISES.

The largest and most important irrigation enterprises in the State are situated in the region adjacent to the Black Hills, comprising the counties of Butte, Meade, Lawrence, Pennington, Custer, and Fall River. Some of these systems are of considerable magnitude and most of them have been in operation for a number of years. They were practically all constructed as private or corporate projects—that is, without public assistance. A brief description of the principal irrigation systems of this character will be given.

REDWATER CANAL.

This ditch is the property of the Redwater Land and Canal Company, a corporation which operates the enterprise on a commercial basis, furnishing water to farmers for irrigating. The head gate is situated about 5 miles above the mouth of Redwater River, from which stream the water is taken. The total length of the canal is 42 miles, but only 30 miles is in use, the lower 12 miles having been abandoned. The company claims the right to appropriate 100 cubic feet per second of water from Redwater River, but it is evident that this amount is not used at the present time. The U. S. Geological Survey has published [a] a tabular statement of the monthly discharge of this canal at Minnesela, a point near its head, during the period from May 27 to October 31, 1906. From this table it is seen that the mean monthly discharge ranged from 10.5 cubic feet per second in June to 70.5 cubic feet per second in July. The area irrigated is stated to be about 5,000 acres, and under the State water law, which allows an appropriation of 1 cubic foot per second for each 70 acres, a flow of 71.4 cubic feet per second could be required, which corresponds closely to the maximum measured flow. With careful husbandry the duty of water in this locality can be increased considerably, and it is probable that the canal could easily be made to irrigate from 8,000 to 10,000 acres.

The price charged to farmers for the water is $1.50 per miner's inch per year, the miner's inch being, under the old water law, equivalent to one-fortieth cubic foot per second, the same as the Montana standard. For small garden patches the company charges $1.50 per year for each acre irrigated. Water is supplied to about sixty customers, the flow being regulated and measured by weirs at the lateral head gates.

The cost of irrigating, in addition to the water rent, is about 50 cents per acre. Since the larger tracts use less than a miner's inch of water per acre, a fair estimate of the total cost per acre would be $1.50. The cost of keeping up this canal is about $600 a year, which is paid by the company. Each water user maintains his own laterals.

EDGEMONT CANAL.

This canal was constructed in the early nineties by the Edgemont Company for the purpose of irrigating a tract of about 4,000 acres in the Cheyenne River Valley. A short while after its completion the company suspended operations, and the canal was abandoned. There has been considerable litigation about possession and owner-

[a] U. S. Geol. Survey Water-Supply and Irrigation Paper No. 208.

ship, and for some years very little irrigation was done. The point of diversion is on the Cheyenne River a short distance below the mouth of Beaver Creek, and the canal extends down the valley on the south side of the river a distance of 14 miles to the town of Edgemont, in Fall River County. The land under the ditch is for the most part flat, with a gentle slope toward the river. The soil is fertile, and the conditions are excellent for successful irrigation. The canal has been repaired recently and is now in active use. Arrangements have been made to irrigate 2,000 acres of land. The stated capacity is 40 to 50 cubic feet per second, so there will be ample facilities for supplying water to as much as 3,000 acres when this canal is in full operation. There are no figures available to show the cost of irrigating land under this canal. The original cost of the canal is stated to have been $88,000, but the present owners purchased the property for an amount very much smaller. Considerable money, however, has been expended in repairing the canal and placing it in first-class condition.

CASCADE DITCH.

This is one of the most successful private irrigation enterprises in the State. It was constructed originally by Herman Mahler for irrigating his own land, but the ditch has been enlarged and extended to supply the needs of the neighboring farmers until its full capacity has been reached. It is now the property of his successors, the Cheyenne Valley Ranch Company. The source of supply is a group of springs situated in Fall River County, about 10 miles southwest of the town of Hot Springs. These unite and form Cascade Creek, a tributary of the Cheyenne River. The point of diversion is about a mile below the springs, the water being taken out by simply turning the main flow of the creek into the ditch through a diversion channel. The upper portion of this ditch supplies water to eight farmers, including the present proprietors. About 900 acres of land are irrigated from this section, requiring a flow of 13 cubic feet per second of the total flow of 30 cubic feet per second. The remainder is distributed among the several adjacent farmers in proportion to their acreage of irrigable land. These irrigators are charged a uniform rate of $1.50 per acre per annum for each acre irrigated. The company keeps up the main ditch and the irrigators maintain their individual laterals. An extension of this ditch beyond the original terminal has been made by a company which owns a water right covering the remaining 17 cubic feet per second. This extension is 12 miles long and carries the ditch into the valley of the Cheyenne River below the mouth of Cascade Creek. This company owns about 2,600 acres of fine land under the extension and intends to utilize their share of the water on this area as far as it will go.

IOWA AND HAWTHORNE DITCHES.

These two ditches are typical of a large number of irrigation systems in use in Rapid Creek Valley. They are owned by the farmers who irrigate from them and are in that sense community ditches. The Iowa Ditch is the highest irrigation ditch now being operated in Rapid Creek Valley. Its head gate is situated within the limits of Rapid City, above which point little irrigation is done at the present. The ditch is 6 miles long and has a capacity of 15 cubic feet per second. There are 1,023 acres of land under it, which is as much as can be taken care of under present conditions. The grade of this ditch is rather light, and, since Rapid Creek has a heavy fall, an elevation considerably above the lower part of the valley is soon attained. This is advantageous in one way, since it permits the irrigation of a large area of irrigable land at some distance from the creek. It would be better, however, to have a heavier fall in order to create sufficient current to carry down the fine silt and other suspended matter in the water, instead of having it deposited in the channel, as is the case at present. It is asserted that the projectors of this ditch intended to extend it for a distance of about 30 miles below Rapid City, in order to take in a large body of fine land situated largely on the ridge between Rapid and Box Elder creeks. This ambitious project was found to be impracticable under existing conditions, the main difficulty being the lack of sufficient water. The Iowa ditch is junior in priority of right to appropriate water to a number of ditches lower down the valley, and during the irrigation season the water supply is subject to the needs of prior appropriators. It is claimed now that the ditch can easily be extended as originally designed, since a water supply can be obtained by means of storage reservoirs to be located at suitable places along the route and filled by the flood flow from Rapid Creek. No surveys have been made to determine the feasibility of this proposition.

The Hawthorne Ditch, including a proposed extension, is 8.5 miles long and has a stated capacity of about 30 cubic feet per second. The head gate is situated about 1.5 miles below Rapid City, the water being turned into the ditch by means of a diversion dam. There are 1,028 acres of irrigable land under the ditch, and the water supply is barely sufficient for this area, especially during the season when the other ditches along the stream are using water. This ditch is operated on the community plan, the stockholders being owners of the land under it. No figures are available showing the cost of irrigating land under this ditch, but it is thought that this will not exceed $1.50 per acre.

OTHER IRRIGATION WORKS.

There are a number of private irrigation works on various streams in this part of the State, the greatest development being in the valleys of Spearfish and Rapid creeks. The facts relating to irrigation in the Spearfish Valley are given in the following table:

Irrigation ditches in Spearfish Valley.

Name of ditch.	Date of completion.	Volume carried.	Length.	Area irrigated.
		Cubic feet per second.	*Miles.*	*Acres.*
Spearfish Creek:				
Gregg & Mathews	1878	4.4	2.0	150
Mathews & Son	1877	15.0	1.5	250
Walton & Co	1877	10.6	3.5	450
Mann	1877	2.0	2.0	80
Fred Ackles	1877	5.9	3.0	190
Evans & Co	1876	19.2	2.5	800
J. E. Cook & Co	1878	7.2	2.5	1,320
Kemper & Dorset	1877	11.4	2.0	300
Parsons & Cogal	1897	.9	1.25	40
Wm. Cook & Co	1877	4.2	3.0	670
Bowman & Co	1878	7.0	1.5	360
Wm. Cook & Co	1877	3.5	1.5	200
Spring Creek:				
Wells	1877	1.03	1.5	100
Toomey	1877	4.2	1.25	225
Lindley	1876	5.09	1.25	200

The following tabular statement comprises the other smaller irrigation systems under private ownership in the State, including those already described and those now under construction. They are arranged according to the water districts into which the State is divided.

Ditch, date for completion, water carried, area irrigated, and length of newer projects, by districts.

Ditch.	Date for completion.	Volume carried	Area irrigated.	Length.	Remarks.
Little Missouri water district:		*Cubic feet per second.*	*Acres.*	*Miles.*	
Roy S. Scott	May 31,1910	4.4	480.00	3.87	Diversion dam and storage reservoir.
Clyde C. Gilbert	Dec. 19,1908	2.0	145.00	.22	Do.
Bertha G. Davis	Aug. 26,1908	1.0	68.00	.47	Do.
George Bonefield	Jan. 20,1911	2.2	151.77	.76	Do
Grand River water district:					
Sarah F. Cox	Oct. 23,1909	2.5	172.32	1.43	Diversion dam.
Emily Peck	June 15,1911	4.5	638.79	2.00	Storage reservoir.
H G. Stolzenberg	July 27,1910	1.75	120.00	.9	Pumped from Grand River.
A. A. Zimmerman	July 24,1910	2.0	100.00	.8	Storage reservoir.
Minnie Zimmerman	....do	3.0	170.00	1.3	Do.
Moreau water district:					
Dena S. Ackerman	June 28,1910	3.5	234.88	1.125	Do.
William C. Jones	Aug 3,1911	2.0	200.00	1.46	Do.
Belle Fourche water district:					
Louis Barber	Completed	2.5	149.60	1.48	Do.
John O'Connor	....do	2.0	160.00	1.54	Do.
Wm. M. Fieldsend	....do	1.5	85.14	2.00	Do.
A. A. Fieldsend	....do	2.5	150.39	3.05	Do.
I. H. and F. S. Chase	Oct. 15,1908	6.5	445.00	2.00	Diversion dam.
Geo. Couch, No. 1	Nov. 6,1910	2.0	106.56	.40	Storage reservoir.
Geo. Couch, No. 2	....do	1.0	12.00	.15	Do.
Tylta Sundquist	Feb. 21,1910	3.5	39.25	.68	Do.
Louise M. Cates	Apr. 17,1910	1.0	22.00	.13	Do.
M. G. Simmons	May 21,1909	2.3	161.00	2.20	Do.

Ditch, date for completion, water carried, area irrigated, etc.—Continued.

Ditch.	Date for completion.	Volume carried.	Area irrigated.	Length.	Remarks.
Belle Fourche water district—Continued.		*Cubic feet per second.*	*Acres.*	*Miles.*	
S. C. Simmons	May 25,1909	3.0	211.00	2.41	Storage reservoir.
E. A. O'Connor	Dec. 13,1909	5.0	351.35	2.11	Do.
P. J. O'Connor	Dec. 13,1912	2.5	142.20	.43	Do.
W. & F. P. Devinney	May 11,1912	3.0	209.99	.54	Do.
H. & E. Went	May 20,1909	4.0	325.92	1.93	Do.
Frank M. Hill	Aug. 5,1911	3.5	290.94	.87	Do.
Other owners	Completed		2,253.00		
Elk Creek water district:					
E. E. Whitmore	June 22,1909	1.0	80.00	.50	Diversion dam.
A. H. Bolt	Oct. 16,1908	1.0	30.00	.30	Do.
Loranger & Jarvis	do	1.0	5.00	.25	Do.
Ewell Hanks	Oct. 28,1908	1.0	40.00	.40	Do.
W. G. Hanks, No. 1	Apr. 21,1913	.78	54.80	.95	Do.
W. G. Hanks, No. 2	do	2.72	190.40	.94	Do.
Geo. McFarland	Mar. 12,1909	2.0	140.00	1.45	Storage reservoir.
Ham & McFarland	Aug. 11,1910	3.70	262.00	4.13	Do.
Rapid Creek water district:					
Burke & Murphy	Completed	6.00	400.00	.38	Diversion dam.
Isabel Humphrey, No. 1	Oct. 15,1908	1.50	100.00	.96	Storage reservoir.
Isabel Humphrey, No. 2	do	1.75	110.00	1.10	Do.
August Mallow	Oct. 18,1908	4.77	334.00	2.05	Do.
Patton Live Stock Co	Completed	22.90	1,603.00	6.00	Diversion dam and storage reservoir.
Iowa Ditch Co	do	15.00	1,028.00	6.00	Diversion dam.
John Hart	June 21,1912	9.30	650.80	4.11	Do.
L. D. Taylor, No. 1	Completed	3.00	212.00	1.10	Do.
L. D. Taylor, No. 2	Aug. 20,1912	8.10	568.30	2.20	Extension old ditch.
Hawthorne Ditch Co., No. 1.	Completed	27.00	1,876.00	6.10	Diversion dam.
Hawthorne Ditch Co., No. 2.	Feb. 21,1910	5.25	367.60	2.37	Extension old ditch.
Wm. G. Phillips	do	2.00	130.00	1.00	Diversion dam.
Eugene Holcomb	Aug. 10,1910	10.00	520.00	1.52	Do.
Cyclone Ditch Co	Completed	7.00	950.00	5.00	Do.
St. Germain Irrigation Ditch Co.	do	10.00	1,790.00	8.00	Do.
Lower Rapid Ditch Co	do	18.00	2,470.00	7.00	Do.
Little Giant Ditch Co	do	8.00	430.00	5.00	Do.
Rapid Valley Irrigation Co.	do	17.00	1,365.00	17.00	Do.
Lone Tree Ditch Co	do	30.00	1,284.00	12.00	Do.
Bollman	do	4.30	300.00	6.00	Do.
Hammerquist	do	8.60	600.00	5.00	Do.
Lockhart & Brennen	do	5.00	350.00	2.00	Do.
Sanders	do	1.20	80.00	1.00	Do.
Battle Creek water district:					
G. C. Katsch	Mar. 27,1909	1.90	133.50	1.95	Storage reservoir.
C. B. & M. F. Smith	Completed	2.12	148.66	1.97	Do.
J. C. Snidow, No. 1	July 5,1911	2.26	186.20	2.26	Diversion dam.
J. C. Snidow, No. 2	do	2.00	142.00	1.40	Do.
Fall River water district:					
Woodford J. Smith	Completed	2.27	158.90	4.28	Storage reservoir.
Maggie Smith	do	3.55	249.04	1.80	Do.
Hot Springs Irr. and L. S. Co.	do	17.00	2,600.00	12.00	Diversion dam.
Cheyenne Valley Ranch Co., No. 1.	Aug. 3,1909	1.00	50.00	1.00	Do.
Cheyenne Valley Ranch Co., No. 2.	Completed	12.54	877.70	3.85	Do.
Ira U. Pickett	Nov. 29,1912	8.00	640.00	2.48	Storage reservoir.
G. W. Wattles	Mar. 30,1910	2.50	60.00	2.00	Flowing springs.
J. P. Billups	Completed	.25	10.00	.18	Water wheel.
G. M. Trimmer	do	.20	5.00	.12	Diversion channel.
South Cheyenne water district:					
J. H. Soske	do	2.00	44.00	.50	Storage reservoir.
Sam Franzen	do	8.50	349.50	5.10	Do.
Dennis O'Connell	May 23,1910	1.50	120.00	1.20	Do.
C., B. & Q. Ry. Co	Sept. 27,1908	90.00	.50	.10	Do.
Laura J. Mudge	Oct. 7,1912	6.00	320.00	1.05	Do.
Effie Soske	Sept. 26,1911	2.00	140.00	3.68	Do.
Andrews & Eckard	Dec. 10,1909	5.00	480.00	3.50	Do.
Heppner Co	Feb. 21,1913	4.00	960.00	2.23	Do.
Jacob Kircher	Completed	2.00	240.00	1.75	Do.
Sophia Kircher	do	2.00	75.00	.75	Do.
D. D. & N. S. Tubbs	May 29,1913	24.00	1,140.00	7.20	Diversion dam.
Edgemont Canal	Completed	28.58	2,000.00	14.00	Do.
A. F. & G. G. Shirk	June 13,1910	12.00	480.00	3.49	Storage reservoir.

The foregoing are the principal irrigation works under private enterprise that are in operation or under construction in the State at the present time. A large number of individual works have been constructed under the provisions of the desert-land act on public lands, and much land is now being reclaimed in this manner. These works comprise the storage of flood waters in gulches or valleys where there are no running streams, and the State water laws have not required formal permits from the State engineer in such cases, but have allowed such appropriations to be made by posting notice on the site. This provision has also applied to all storage works on what are known as "dry draws" and has resulted in much confusion. The records of the State engineer's office have not been completed so as to show the extent of such irrigation enterprises, and only a rough estimate of them can be made at this time. It is thought that the amount of land coming under this head will approximate 14,000 acres.

SMALL RESERVOIRS.

An important factor in the irrigation work of the State is the use of small reservoirs for irrigating small tracts of land. There are a great many such reservoirs in western South Dakota, situated principally on the prairies above the reach of gravity flow from running streams and dependent on the precipitation upon the catchment area above them for water supply. While the area irrigated by an individual reservoir system is necessarily small, the aggregate area reclaimed by them all is quite large. A typical instance of reservoir irrigation is that of the Barbour reservoir, described in a previous bulletin of this Department.[a] These three reservoirs were built on a homestead 5 miles northeast of Belle Fourche, and have a water surface when full of about 7 acres and a capacity of about 25 acre-feet. The country is rolling and the stream upon which they are located is what is known as a "dry draw;" it is called the West Fork of Basin Creek. The site is a basin formed by erosion, and serves incidentally to prevent further erosion.

The dams are earthen structures from 100 to 150 feet long and originally had a top width of 10 feet, a water slope of 1 to 2, and a rear slope of 1 to 1½. The material, a mixture of gumbo and silt, which quite easily eroded and dissolved, is the only material available. These dams were evidently built without engineering supervision, and are not cited as examples of suitable construction for this class of work. They were built before the enactment of the present State water code, which requires that all dams built under the supervision of the State engineer, if of earth, shall have a water slope of 1

[a] U. S. Dept. Agr., Office Expt. Stas. Bul. 179.

to 3 and a back slope of 1 to 2. This design possesses a good factor of safety, but it requires considerably more labor and material than the average farmer or ranchman thinks necessary to supply. The direction of the prevailing wind is quartering to the dams; therefore the waves are not so high nor their force so severe as would be the case if the wind blew directly over the dam. Such waves as there are, however, have given the two upper dams a terraced appearance in place of the regular slope. The top widths have been reduced, notably in one case, to less than 6 feet. Effort has been made to prevent this in one dam by means of a tight board fence, but no braces were provided to give rigidity and it is now in a very dilapidated condition. At the lower dam cottonwood trees have been planted as a wave protection. The provisions above noted for wave protection are very crude and inadequate, and might have been rendered much more effective if proper engineering advice had been obtained by the proprietor of the reservoirs.

The wasteway delivering the surplus water into the lower reservoir is ample, but cutting has begun at its lower end, owing to the rapid fall of the water. An effective prevention would have been obtained by the use of stone paving or by means of a thin coat of concrete on the bottom and sides of the wasteway.

The outlets of the reservoirs are all wooden boxes having cross-sectional areas of less than 0.5 square foot, fitted at the upper end with sliding wooden gates and manipulated from footbridges directly above them. These outlets will soon decay and replacement by some more permanent material will be rather difficult. The amount of silt deposited even in the upper reservoir has been very small, due to the facts that the surface of the tributary area is well sodded with native grasses and that the capacity of the reservoirs is comparatively large in comparison to the area of the catchment basin, it being probable that the reservoirs are filled but once each year. From the lower reservoir a ditch leads to the land to be irrigated. Because of the rapid slope of the land, this ditch is but a few hundred feet long. The water is used to irrigate about 20 acres, of which 10 was planted to corn and 10 to alfalfa.

Since these reservoirs have been in operation another set of three similar ones has been constructed on the East Fork of Basin Creek, a short distance away. These latter reservoirs were built for the purpose of reclaiming land under the desert-land act. They are larger than those first built, having a combined capacity of 54 acre-feet and being intended for irrigating 125 acres of land. They have been in operation a comparatively short time, but the results so far in the way of irrigation have been satisfactory. The later reservoirs are more substantially built than the former, having wider bases and being

protected against wave wash by stone riprap. They are owned by Louis Barbour, who cultivates the land irrigated from them. The total cost of all the dams, including the three constructed first, is stated to have been $1,000; since their combined capacity is 79 acre-feet, this would make about $12.66 per acre-foot of storage. The cost of the ditches is given at $500.

The above-described system is a fair example of storm-water reservoirs and methods of irrigation therefrom in South Dakota. A great many reservoirs similar in construction and operation are in use in Butte County alone, and these afford very favorable results when local conditions are taken into consideration. The construction of small reservoirs for impounding storm water in South Dakota is encouraged by the State engineer's office, for the reason that such reservoirs are useful in storing and retaining part of the run-off of each rainfall which would otherwise go quickly into the larger streams. In this way some good results are obtained in mitigating the effects of overflow and flooding by the larger streams. Of course, no very great amount of water in any one stream system is thus held back, but in the course of time it is hoped a decided benefit in this respect will be effected when the number of reservoirs for impounding storm waters has been increased to the maximum.

BEAVER CREEK RESERVOIR.

In the southwestern corner of the State, near the Wyoming line, an irrigation project was undertaken in 1896 by the Beaver Creek Irrigation and Canal Company. A reservoir was built by this company for the purpose of irrigating land in the valley of the Cheyenne River and its tributary, Beaver Creek, lying north of Edgemont. The reservoir is one of the very few private reservoirs which had engineering supervision during construction and which shows careful designing. It has a capacity of 1,405 acre-feet. The position occupied by the reservoir is a commanding one, and by filling but once a year between 600 and 700 acres could be thoroughly irrigated. Work was begun on this enterprise March, 1896, and was continued until completion. In connection with the reservoir the Farmers' Union Ditch was completed as far as the State line between Wyoming and South Dakota. Soon after construction the reservoir was filled to the high-water line and has not been used since. For several years past the water surface has remained at a nearly constant position, about 12 feet below the top of the dam. This irrigation enterprise has been tied up in controversy and litigation and has been a source of expense instead of a benefit to the land. The use of the water on the land would have been a considerable factor in the development of Fall River County, and would have afforded an excellent object lesson of

the benefits of irrigation to that portion of the State. Unfortunately, however, the reservoir is situated in Wyoming, while the land to be irrigated lies principally in South Dakota, thus bringing up the unsettled question of appropriation from interstate streams.

STORM-WATER FLOODING.

Another method of storm-water irrigation is by the temporary changing of the flow of a stream from its natural channel to higher ground on either side. This is effected by means of small check dams, which are built at intervals across the channel of a dry watercourse and serve to divert the flow of the storm water through wasteways from the ends of such dams through channels leading therefrom to the high ground. In this way a considerable amount of water is diverted onto the land that would otherwise not receive more than the normal rainfall. In this way ground that ordinarily receives comparatively light rainfall is made to receive a sufficient quantity of water to provide for vegetation requiring a comparatively large amount of rain. In many localities throughout South Dakota, especially in Pennington, Mead, and Butte counties, this method of irrigation is successfully practiced. It is well adapted for the production of hay crops and is used principally for this purpose, yet in some cases good crops of cereals are produced thereby.

NEGLECTED AGENCIES.

There has been no organized effort in South Dakota to form irrigation districts for aiding the construction of irrigation works. That section of the State where irrigation is required for crops is not sufficiently settled and populated to maintain district organizations. Such agencies have operated successfully in other States, and it is probable that they will be utilized in this State in due course of time.

The provisions of the Carey Act have not yet been accepted by South Dakota. A bill was introduced in the State legislature in 1907 providing for the acceptance of the Carey Act, but failed of passage because of lack of public interest. In view of the immense development in the reclamation and settlement of parts of other States that has taken place under the provisions of this National law it is believed that similar benefits would follow its adoption by South Dakota. This act, while entirely independent of the Reclamation Act, does not necessarily conflict or interfere therewith. There is room for both to operate, side by side, in the State.

RECLAMATION PROJECTS.

The Reclamation Service has now under construction in this State one large reclamation system, the Belle Fourche project. It has also

under consideration the Grand River project, covering an area of 10,000 acres, situated partly in North Dakota and partly in South Dakota.

THE BELLE FOURCHE PROJECT.

This immense reclamation project was begun in 1903 and is now well on the way to completion. In the Sixth Annual Report of the Reclamation Service the following data relating to this project are given:

The location is in Butte and Meade counties, occupying townships 6 to 10 north, ranges 3 to 8 east, Black Hills meridian. The altitude is 2,600 to 3,000 feet. The Chicago and Northwestern Railway is adjacent, the Chicago, Burlington and Quincy Railway 14 miles southwest, and the Chicago, Milwaukee and St. Paul Railway 50 miles southeast of the project.

The principal markets are Omaha, Sioux City, Chicago, Minneapolis, St. Paul, and mining towns in the Black Hills. The United States land office is in Rapid City. The irrigable area is located in townships 7 to 10 north, ranges 2 to 7 east, Black Hills meridian. The extent east and west is about 40 miles and north and south about 13 miles; average elevation, 2,800 feet. The character of the soil on the north side of the valley is clayey loam and on the south side sandy loam. The temperature ranges from 100° to —30° F. The average annual rainfall is 14 to 18 inches; the size of the farm units is 80 acres of irrigable land; the value of irrigated lands is $75 to $100 per acre; the principal products are alfalfa, grain, vegetables, hardy fruits, sugar beets, and native hay; the duty of water is 2 acre-feet per annum; the watershed is 4,300 square miles; the average rainfall in the mountains is 18 to 25 inches; the average annual discharge of the Belle Fourche River at the head of the inlet canal is 400,000 acre-feet; storage reservoir, 8,000 acres; capacity, 203,770 acre-feet. The storage dams are of earth with concrete revetment; length on top, 6,200 feet; maximum height, 115 feet. The diversion dam in the gravity section is of concrete; length, 400 feet; height, 23 feet. The main canals have a total length of 100 miles; width on bottom, 14 to 40 feet. The lateral canals have a total length of 125 miles; sublateral canals, 1,000 miles.

A reconnaissance survey of the Belle Fourche Valley was begun on July 8, 1903, with the view of providing for the irrigation of part of it with the waters of the Belle Fourche and Redwater rivers, which were going to waste each year. On May 10, 1904, the construction of the project was authorized by the Secretary of the Interior. On July 20, 1904, the Belle Fourche Valley Water-users' Association was organized by the residents of the valley who owned private lands under the proposed system, the total area being represented by 100,000 shares of stock of a total value of $3,400,000.

Final surveys and plans were made during the summer of 1904, and on April 10, 1905, bids were opened at Denver, Colo., for the diversion dam, the main feeder canal, and structures on the main feeder canal. Contracts were awarded on April 24 and 26, and construction work was started immediately and has been carried on continuously since that time. The project contemplates the reclamation of 100,000 acres, in the Belle Fourche Valley, beginning about 2 miles east of the town of Belle Fourche and extending east 40 miles. The valley lands on both sides of the river are included in the irrigable area. The main supply canal and diversion dam have been completed and the water turned in. The waters of the Belle Fourche River run through this canal and are to be stored in the Belle Fourche Reservoir, which will hold sufficient water to

irrigate completely all lands in the project except about 4,000 acres, which is above the reservoir and will receive water from the river.

Two canals carry the water from the reservoir to the lands. One, the North Canal, runs in a northerly and easterly direction and serves land in Indian, Horse, Dry, and Willow Creek valleys. The other, the South Canal, runs in a southerly and then easterly direction and irrigates lands in Owl Creek Valley and on the south side of the river in the vicinity of Vale and Empire.

The first section of the South Canal has been completed, and during 1908 water has been furnished to about 8,000 acres of land under it and to 4,000 acres under the Inlet Canal. The area that will receive water will be increased each year as the different canals are completed until the final completion in 1910.

Main Supply Canal.—The inlet or main canal is 6.5 miles long and runs from the Belle Fourche River to the reservoir. It will be used chiefly to fill the reservoir, there being about 4,000 acres of irrigable land under it. The canal is 40 feet wide on the bottom and 70 feet wide at high-water line and carries 10 feet of water. The grade is 1 foot per mile and the capacity 1,635 cubic feet per second. The water enters the canal through a concrete regulator. At Crow Creek, a half mile below the regulator, a wasteway and set of three sluicegates are located. At the lower end of the canal a concrete weir or overflow 180 feet long, with a concrete apron, has been constructed to drop water from canal to reservoir. Water will flow over the weir only 2 feet deep when the canal is running full. The structure is so arranged that the canal can be emptied through an opening at the lower end.

Diversion dam and regulator.—The dam in the Belle Fourche River is used to raise the water in the river about 8 feet and divert the flow to a depth of 10 feet into the canal. The dam consists of a concrete weir or overflow 400 feet long, founded on bed rock and connected on the south side with an earth wing dam 1,300 feet long, which is paved on the water slope, or upper side, with 18 inches of stone. The regulator at the head of the supply canal consists of seven openings, each 5 feet wide, the water being controlled by double gates operated by ball-bearing pedestals. There are also three gates of the same size through the dam, used as sluicegates, or to waste the water down the river if desired without forcing it over the weir. The above-described works are completed and ready for use.

Belle Fourche dam.—This dam, which is being built across Owl Creek, 12 miles northeast of the town of Belle Fourche, will, when completed, be one of the highest earthen dams in the United States. The water will be backed up Owl Creek about 10 miles and a water area of 8,010 acres produced, having an available storage of 203,770 acre-feet. The dam is built of earth, watered and rolled in 6-inch layers. The water slope will be protected by 2 feet of gravel on which a facing of 8 inches of concrete will be placed. The outer slope will be seeded to grass to protect it from wash. There are two conduits through the dam, one at the head of the North Canal and one at the head of the South Canal. These are reenforced-concrete structures, and the water is controlled by cast-iron gates. The dam, when completed, will be 115 feet high at the highest point and 6,200 feet long on top. An overflow wasteway capable of discharging 3,000 cubic feet per second is to be provided.

North Canal.—This canal will be 45 miles long. The first section has been completed and is ready for use. The main structures on it will be the Indian Creek and Horse Creek pressure pipes. The first section of the canal is 32 feet wide on the bottom, carries 7 feet of water, and has a capacity of 650 cubic feet per second.

South Canal.—This canal will be 45 miles long. The first section has been completed and is ready for use. It is 18 feet wide on the bottom, carries water to a depth of 5.5 feet, and has a capacity of 320 cubic feet per second. The main structures to be built are two wasteways, the Belle Fourche, Anderson, and Whitewood pressure pipes, and a tunnel 1,295 feet long. The total length of the siphons or pressure pipes is 4,600 feet. Work is in progress on these structures.

Laterals.—The construction of the system of lateral ditches for about 25,000 acres, or one-fourth of the irrigable area, has been completed, and these will be ready for use when water is turned into the larger canals.

Irrigable lands.—The irrigable land under the project begins about 2 miles below the diversion of the Belle Fourche River and extends east for 40 miles, including, besides the valley of the Belle Fourche River, those of Indian, Owl, Horse, Dry, Antelope, and Willow creeks on the north side and Whitewood, Cottonwood, and Nine Mile creeks on the south side. Fine crops are now raised in these valleys in years when the rainfall is sufficient, but crops can not be depended upon without irrigation.

Many of the farm units contain, besides 80 acres of irrigable land, 40 or 80 acres of high or rough land which can not be irrigated, but is valuable to the settler for grazing or in occasional years for dry crops. The open range extends to a great distance on all sides of the project and affords excellent summer feed for the herds of the settlers.

The total irrigable area is 100,000 acres, divided into more than 1,000 farms. The slope of the land ranges from very flat on Indian Creek to rolling on Willow Creek. The soil is all fertile and free from alkali and stone. The natural growth in its wild state is sagebrush, cactus, and wild-wheat grass. Wherever there is water a good growth of timber is found along the many creeks.

Town site.—A tract of land, 640 acres in area, has been reserved for a town site. This is located near the center of the project and it is thought it will be the center of a large farming community after the system is in operation. The land will be laid off into streets, blocks, etc., and the lots will be appraised and sold at public auction. It is expected that the proceeds of the sale will be available for municipal improvements, schoolhouses, parks, and streets.

GRAND RIVER PROJECT.

In February, 1907, the United States Government, through H. N. Savage, a supervising engineer of the Reclamation Service, appropriated the waters of the North Fork of Grand River, in Butte County, for irrigation purposes. The appropriation was made for the lands covered by the Grand River project, which is to be undertaken by the U. S. Reclamation Service. This project covers about 10,000 acres, of which about 7,000 acres is in North Dakota and 3,000 in South Dakota. It is proposed to form a water users' association, composed of settlers in both States. Some action will soon be taken in the matter. The land is productive and well adapted for irrigation.

OTHER PROJECTS.

Other irrigation projects in the State have been considered. Examinations or reconnaissances of these have been made by engineers

of the Reclamation Service. Preliminary reports have been published and the results are given here. The officials of the Reclamation Service have not indicated that there is any probability of taking up any of the projects considered, but it is thought that one or two of them might be carried out under the Carey Act in the event this act is made applicable to South Dakota. The following reconnaissance reports are taken chiefly from the Third Annual Report of the Reclamation Service:[a]

Rapid Creek reconnaissance.—There is probably some water available for storage from Rapid Creek, if the amount needed for lands now in cultivation below Rapid Creek is used economically and none is wasted. The best land available for reclamation is on the north slope of Box Elder Creek and is mostly in private ownership. To reclaim this area all the spring and flood flow of Rapid and Box Elder creeks must be stored. The only feasible site is on Box Elder Creek near the town of Black Hawk, to reach which a diversion of Rapid Creek must be made about 6 miles above Rapid City. This diversion would interfere with two plants at Rapid City that use the water for power purposes, unless arrangements for local storage at the point of diversion could be made. There is probably sufficient water available to reclaim 20,000 acres if the above complications were removed. It is thought that storage along the proposed extension of the Iowa Ditch might be sufficient to reclaim about 30,000 acres lower down the valley.

Little Missouri River reconnaissance.—During the summer of 1904 a possible storage system by which the flood waters of the Little Missouri River could be utilized for irrigation was surveyed near Alzada, Mont. Gauging stations were established on the river near the reservoir site and at Camp Crook, S. Dak., near the irrigable land, and a careful record of the available flow was kept daily. The land is mostly owned by the Government and possibly 40,000 acres may be reclaimed. Railroad facilities come within reach of this territory.

Cheyenne River reconnaissance.—A reconnaissance was made of the upper watershed of the Cheyenne River for possible reservoir sites in the summer of 1904. None was found on the main river that could be constructed at a cost warranted by the amount of land to be reclaimed. Possible sites were located at Hat and Beaver creeks and as nothing was known of the flow of these creeks gauging stations were established so that a careful study of the water supply of each could be made. The Cheyenne River has a drainage area of about 7,350 square miles above Edgemont. The stream is sandy and dry for a large part of the summer, although subject to floods in the springtime from melting snow and through the summer from sudden storms.

About 40,000 acres of first-class land are situated along this river, but even if the water supply should be satisfactory the cost of reclamation would be high on account of the irrigable tracts being scattered, requiring long and expensive canals. The land is mostly in private ownership.

PRESENT AND PROSPECTIVE IRRIGATED AREA.

From the foregoing statements the following table has been compiled, showing the areas that are now under irrigation, including

[a] United States Reclamation Service, Ann. Rpt. (1904), pp. 492, 493.

those to be supplied with water January 1, 1909; also areas that will be reclaimed when present undertakings are completed:

Areas under irrigation works and projects.

Project.	Areas to be under irrigation by January 1, 1909.	Additional area to be reclaimed under present projects.	Project.	Areas to be under irrigation by January 1, 1909.	Additional area to be reclaimed under present projects.
	Acres.	*Acres.*		*Acres.*	*Acres.*
Redwater Canal	5,000.00		Grand River water district		1,201.11
Spearfish Valley	5,335.00		Moreau River water district		434.88
Little Missouri water district	213.00	631.77	Belle Fourche project	12,000.00	88,000.00
Belle Fourche water district	3,242.13	1,872.21	Reservoir filings (estimated)	14,000.00	30,000.00
Elk Creek water district	75.00	727.20			
Rapid Creek water district	15,278.00	2,237.60			
Battle Creek water district	148.66	461.70	Total	61,901.03	129,956.47
Fall River water district	3,900.64	750.00			
South Cheyenne water district	2,708.60	3,640.00			

COST OF LAND AND WATER.

The original cost of the Edgemont Canal, built about fourteen years ago by the Edgemont Company, is stated to have been $88,000. This amount includes the cost of headworks and ditch; also protective works. There were about 2,200 acres of land under this project, which would indicate a cost of $40 per acre for the water under original conditions.

The owners of the Cascade Ditch, in Fall River County, report a total cost of $13,750 for their ditch and headworks, under which 877.7 acres are irrigated; equivalent to a cost of $15.67 per acre for the water. The construction is simple and comparatively cheap, since no dam is required at the headworks for diversion or storage. The water is conducted through a head gate in the bank of the creek directly into the ditch without the need of dam or weir.

With regard to the cost of land and water under the Belle Fourche project, the figures given here are taken from statements made by officials of the Reclamation Service. In round numbers there is 100,000 acres of irrigable land under this project, of which 50,000 is subject to homestead entry, 45,000 under private ownership, and 5,000 is State land. The Government land subject to entry can be obtained by settlers subject to the usual charges and fees for homestead entries. The land under private ownership can be obtained for prices ranging from $10 to $15 per acre. The State land can be bought at a minimum price of $10 per acre. These prices refer to irrigable lands under this project. In addition to these charges for the land a charge of $30 per acre will be made for water rights and irrigation works.

LAWS GOVERNING THE CONTROL AND USE OF WATER.

Prior to the year 1905 there was no State supervision of flowing streams in South Dakota, and local customs were followed in the matter of appropriating water for beneficial purposes. In the western part of the State considerable placer mining was done in the gulches and along the streams in the Black Hills. Such operations required the use of flowing water in most instances, and in such cases the appropriation could be made by posting a notice on a post or tree at or near the point of diversion. In some instances a copy of the notice was filed at the court-house of the county in which the appropriation was made, and the appropriation thus became a matter of record. Most of these placer workings have been abandoned, and the water rights in such cases have lapsed from nonuse. In this way the records show a large number of appropriations of water which are no longer valid, but which will require careful investigation to separate from those remaining in full force and effect.

The State laws authorized appropriations of water in the manner described, and the general custom of the country permitted appropriators to place on record such claims to the water supply as they deemed advisable. The natural tendency was to make the claim large enough to cover all possible requirements, and in most cases greater than there was any expectation of using. This resulted in many instances in absurd and speculative claims, and the records show numerous cases where each of a number of claims to water of a stream, filled in accordance with the former statutes, involved a larger quantity of water than had ever flowed in it, even during flood periods. One provision of the former statutes permitted the acquirement of a water right by usage, and an appropriator under such circumstances was entitled to the enjoyment of such a quantity of water as he actually applied to beneficial use. Such water rights acquired under the old State water laws as have been kept alive are recognized as valid and of full force and effect. The keeping alive of a water right consisted in making beneficial use of the water claimed during a portion, at least, of each year, and failure to use the water for a period of two years constituted abandonment.

In 1905 South Dakota adopted a code of water laws providing for the adjudication of existing rights and the complete public control of the water supply in the future. The office of State engineer was created, and to the engineer was given general supervision of waters of the State and of the measurement and appropriation thereof. This law was amended and reenacted in 1907 so as to make it applicable to all beneficial uses of water without limiting its application to irrigation alone.

The previous law of South Dakota, as above stated, provided for posting and filing notices, as did the laws of other States, and the State engineer has secured from the county officers copies of all such notices. The records show nothing as to what was done under these notices, but the engineer has examined the locations covered by a number of them and found that nothing had been done under those particular ones. Under the present State water law the State engineer is empowered to make all necessary general rules and regulations to carry into effect the duties devolving upon the office.

DEFINING RIGHTS.

The State engineer is to make hydrographic surveys of each stream system and source of water supply in the State and collect and record all available data for the determination, development, and adjudication of the water supply of the State. He is authorized to cooperate with the agencies of the United States engaged in similar surveys and investigations and in the construction of works for the development and use of the water supply of the State, expending for such purposes any money available for the work of his office; he may use in connection with the work of his department the results of the work of the agencies of the United States. Upon the completion of such hydrographic survey of the several stream systems of the State, the same shall be filed in the office of the State engineer as a part of the records thereof, to be used as evidence in suits for the adjudication of water rights.

In any suit for the determination of water rights all who claim rights to the same source may be made parties, and the court is to call upon the State engineer to furnish complete hydrographic surveys and obtain all data necessary for a determination of the rights. The costs of the suit, including all work done by the State engineer, are to be charged to the parties in proportion to the amount of the water right allotted to them. For the purpose of meeting these expenses an appropriation of $1,000 was made, to be replenished by the money collected from the parties, thus becoming a permanent fund. Upon the completion of an adjudication the clerk of the court is to make two certified copies of the decree, one to be filed in the office of the State engineer and the other in the office of the water commissioner of the water division in which the stream is situated. Such decree shall in every case declare as to the water right adjudicated to each party, the priority, amount, purpose, place of use, and in the case of water used for irrigation, the specific tracts of land to which it shall be appurtenant, together with such other conditions as may be deemed necessary to define the right and its priority.

ACQUIREMENT OF RIGHTS.

Any party hereafter wishing to acquire a right to use water must make application to the State engineer for a permit, giving all the data necessary for the proper description and limitation of the rights applied for, together with such maps, plans, and specifications as are necessary to show the method and practicability of the construction and the ability of the applicant to complete the same. These maps, plans, and specifications are to be furnished in duplicate, one copy to be filed in the office of the State engineer and the other to be returned to the applicant. The application may be returned for correction or addition if defective in form or unsatisfactory as to the plan. Notice of application must be published at the expense of the applicant, and interested parties may be heard for or against the granting of the application. The engineer may reject applications if there is no unappropriated water in the source of supply or if, in his opinion, their approval would be contrary to public interest; but any applicant may appeal from this decision to the courts.

An approved application becomes a permit, and in his approval the engineer must state the time within which the construction shall be completed, not exceeding five years, and the time within which the water shall be applied to a beneficial use, not exceeding four years after the date of completion. One-fifth of the work must be done within half of the time allowed for completion, and in case of failure the engineer may issue other permits for the same supply. But the engineer may extend the time allowed to the original applicant, yet only on account of delays due to physical or engineering difficulties which could not have been reasonably anticipated, or to operation of law beyond the power of the applicant to avoid.

On or before the date set for completion the engineer is to inspect the works in order to determine their capacity, safety, and efficiency. He may require necessary changes, and shall not issue his certificate of completion until such changes shall have been made. When the works are in satisfactory condition the State engineer shall issue a certificate of completion setting forth the capacity of the works and such limitations upon the right as are warranted by the condition of the works, but in no manner exceeding the rights described in the permit.

On or before the date set for the application of the water to a beneficial use the engineer shall again inspect the works and, after the inspection, issue a license to appropriate water to the extent of the actual application thereof to a beneficial use. The inspection for actual completion of the works and that for the application of the water to a beneficial use may be made at the same time if the owner

of the permit wishes this to be done. Any permit or license to appropriate water may be assigned, but no assignment is binding except upon the parties thereto unless it is filed in the office of the State engineer.

ADMINISTRATION.

For the distribution of water the State is divided into three divisions, for each of which there is a water commissioner. In the event of a temporary vacancy in the office of water commissioner, the powers and duties of such water commissioner shall devolve on the State engineer until the office has been regularly filled. These commissioners and the State engineer from a State board of water commissioners, which is to have general supervision of the distribution of water. The engineer may make rules governing distribution, but these may be revised by the board of water commissioners. The divisions are subdivided into districts, which are designated by name and comprise as far as possible one or more distinct stream systems in each district. Anyone may appeal from any act or decision of a water commissioner to the State engineer, from whom appeal may be had to the courts. The water commissioners are appointed by the governor to serve six years, subject to removal by the governor, and they receive $5 per day for the time actually engaged in official duties, not to exceed 100 days in any one year. This is paid by the State.

FEES.

The fees collected by the State engineer are turned into the State treasury. The fees allowed are as follows: For filing and examining an application for permit to appropriate water, map, and field notes of same, which shall include the filing of proofs of publication and all other papers relating to the application up to the recording of a permit to appropriate water, $5; for recording any permit, certificate of construction, or license issued, or any other water-right instrument, $1 for the first one hundred words and 15 cents for each additional one hundred words or fraction thereof; for filing any other paper, $1; for issuing certificates of construction or licenses to appropriate water, $1 each; for making copy of any document recorded or filed in his office, 15 cents for each one hundred words or fraction thereof; for blueprint copy of any map or drawing, 10 cents per square foot or fraction thereof; for other copies of drawings, actual cost of the work; for certifying to such copies, $1 for each certificate; for examining, in connection with water-right applications, plans, and specifications for any dam not exceeding 10 feet in extreme height from the foundations, $10; for a dam higher than 10 feet and not exceeding 30 feet, $20; for a dam higher than 30 feet and not

exceeding 50 feet, $30; for a dam, canal, or other water conduit of an estimated capacity exceeding 50 cubic feet, but not more than 100 cubic feet per second, $20; for an estimated capacity exceeding 100 cubic feet per second, $30; for inspecting dam sites and construction work when required by law or when necessary in the judgment of the State engineer, $10 per day and actual and necessary traveling expenses. The fees for any inspection deemed necessary by the State engineer and not paid on demand shall be a lien on any land or other property of the owner of the works and may be recovered by the State engineer in any court of competent jurisdiction. For rating ditches, for inspecting plans and specifications of works for the diversion, storage, and carriage of water at the request of private parties and not in connection with an application for right to appropriate water actual cost and expenses are charged, and the State engineer shall attach his approval to such plans and specifications if found satisfactory. For such other work as may be required of his office he collects the fees provided by law.

CANALS AND DITCHES.

Ditch owners are required to put in head gates and measuring devices of designs approved by the State engineer, at places determined by him, and in case these structures are not put in within twenty days after notice from the engineer the water commissioner may refuse to deliver water to the ditch. Taking water under these circumstances is a misdemeanor. Interfering with any dam, head gate, weir, or other structure or with any person lawfully distributing water is also a misdemeanor.

The owner or owners of any works for the storage, diversion, or carriage of water which contain water in excess of their needs for irrigation or other beneficial use for which it has been appropriated shall be required to deliver such surplus at reasonable rates for storage, carriage, or both, as the case may be, to the parties entitled to the use of the water for beneficial purposes. In the case of the refusal of such owner or owners to deliver any such surplus water at reasonable rates determined by the State engineer, he may be compelled to do so by the circuit court for the county in which the surplus water is to be used.

This provision is wise and necessary in that it affords a guaranty of a continuance of water rights to landowners who are dependent upon canal owners for water. The water is appurtenant to the land and may not be transferred therefrom except by mutual understanding. These provisions constitute a safeguard for the water user and he can depend upon a normal supply of water under all ordinary conditions.

The State supervision and regulation of the use of water is a protection alike to both parties and guarantees an equitable distribution of the water. It is the common tendency of irrigators to use too much water, and authority given the water commissioner to lock the lateral head gates along a canal serves to check the waste of water when it is needed by other users.

The provisions in the law requiring canal owners to fix reasonable rates for water supplied to other users is a further safeguard to protect water users against exorbitant charges. There are persons who claim sometimes that they are not allowed to have enough water for their crops, but the water commissioner usually makes an impartial distribution to all.

METHODS OF DISTRIBUTION.

The methods employed for distributing the water over the land are generally similar to those used in other States. In the Spearfish Valley the ditches are owned by the water users, and each individual uses what he needs, without regard to the needs of others. This, in the main, is satisfactory here, as there is usually an ample supply of water for all, though occasionally an agreement is made among the users as to the time when each shall be allotted a full flow in his ditch, alternating with the others until all are supplied.

In Rapid Creek Valley there is more land than available water, and during the irrigating season rotation is practiced. Each ditch uses water in turn, and in this way the various users are supplied with what water is required. This valley is practically all under ditch, and there have been several suits over the water rights on Rapid Creek. The rights of the various ditches have been adjudicated by the courts, and each company operates its ditch in accordance with its priority.

The Redwater Canal supplies 63 customers through laterals, the amount of water being regulated and measured by weirs at the lateral head gates. Water is sold at a fixed price, $1.50 per miner's inch per annum for ordinary users, and for small garden patches the charge is $1.50 per acre of land irrigated. There is enough water for all if economically used, but under existing conditions there is often considerable friction between the water users over the distribution of the flow. The ditch company installs head gates at the various laterals, but the irrigators keep their laterals in repair. The company cleans out the ditch every spring for use during the irrigating season, being assisted in this work by the water users, who furnish men and teams for the purpose.

SETTLEMENT OF LANDS UNDER IRRIGATION SYSTEMS.

The prospective settler on irrigated lands should bear in mind that the labor and expense necessary to prepare the land for water are much greater than for land where irrigation is not practiced. The land belonging to the public domain is open to entry under the homestead laws. This land when it is situated under a reclamation project will cost nothing except the filing fees, but the cost of the water for irrigation will have to be paid in addition. On the Belle Fourche project the maintenance charge is 40 cents per acre annually. The building charge is payable in ten annual installments, thus making settlement possible for people of small means. It is necessary, however, for persons who take up these lands to have some capital, sufficient at least for maintenance, farm implements, and other necessaries while a crop is being produced. A house must be built, stables constructed, and domestic conveniences for living provided. A great deal of work is required to care for irrigated land and cultivate it properly. It is often necessary to hire some help to work the ground and this requires a supply of ready cash. Unless a man is prepared to undergo hard work and has sufficient means to support himself and family and to pay expenses the first season it will be useless for him to undertake settlement under an irrigation project. The industrious farmer who is willing to give the same attention to the irrigated farm that he was accustomed to give the farm in the humid region will generally make a success, since irrigated crops are always sure.

It is not possible to say just what amount of capital and equipment are required to make a successful start on irrigated lands. This will depend upon the condition under which the move is made and will vary with individual cases. If a man is able and willing to undertake the labor and care necessary for successfully cultivating irrigated land, comparatively little capital will be required beyond what is necessary for home building and living expenses. It is the opinion of the engineer in charge of the Belle Fourche project that prospective settlers should come prepared to maintain themselves for six months or a year until money crops may be produced from their lands. This would require about $1,000 for an 80-acre tract, on which the first payment would be in the neighborhood of $250. This is a safe and conservative estimate which should be carefully considered by those who contemplate settling on irrigated lands. The amount designated, $1,000, may appear to be quite a sum of money, especially when one has in mind the occupancy of public lands which are open for entry, but it can be advantageously and profitably used in the development of a farm and the upbuilding of a home. If the settler is willing to undergo the hardships incident to a pioneer life he can

put up a shanty at a moderate expense that will shelter him temporarily and by pinching and living very economically make out with a smaller sum. It would seem, however, that at least $500 would be required for a settler to go through the first season and make the first year's crop. This is not making allowance for an equipment of agricultural implements and live stock.

PREPARING LAND FOR IRRIGATION.

In western South Dakota the irrigable land is largely prairie, having a comparatively smooth, uniform surface, with a gentle slope toward some stream valley or natural channel. Such natural conditions are almost ideal, in that a good opportunity is afforded for the flow of water from the higher to the lower ground, and the channel insures good drainage.

The character of the soil is excellent, this being indicated by the natural growth of sagebrush and buffalo grass, which is good evidence that the soil is fertile, easily cultivated, and well drained.

On the lands under the Belle Fourche project the laterals are constructed to each farm unit, and it is necessary for the farmer to construct farm ditches to convey the water to every part of his land. The cost of constructing such ditches will vary according to local conditions. Under ordinary conditions, with the land fairly smooth and regular, the cost of the ditches complete for a tract will be about $200. This includes the cost of lumber for head gate and diversion boxes, which will be about $75. If the farmer has time to do the work himself the only cash outlay required will be for lumber.

After the farm ditches are built the land should be prepared in conformity with them for irrigation. It is important that the new settler take sufficient care to prepare the surface of his fields so they may be cheaply, easily, and properly watered. The preparation of the land, if thoroughly attended to within the first season or two, will necessitate little expense afterwards.

The natural growth of low sagebrush can be readily plowed without the larger plants having to be first removed. Such land should be plowed deep, the larger growth removed, and the ground smoothed. After land has been cleared of brush the most important requirement is a thorough grading of the land to be watered. The freer the surface of the ground from humps and depressions the more uniformly will water flow from it. When once the surface is thoroughly graded one man can apply water to every part of the field with comparative rapidity and effectiveness. Grading should usually be done after the farm ditches have been made, as it will be found that less grading will be required than in reducing a whole farm to a uniform slope.

The leveling, grading, or smoothing of fields for irrigation is generally not a difficult task in western South Dakota. The natural smoothness and uniformity of the prairies make it possible to conduct water over large areas without leveling the ground. In some cases, however, there are tracts of irrigable land where a small outlay will be required to smooth the surface of the fields, and in such cases the cost of this work will be more than repaid through the easier distribution of the water and increased yield of the crops.

The cost of preparing land for irrigation varies with the condition of the ground and the price of labor. The cost of grubbing sagebrush in Wyoming is given as $1.50 per acre, based upon conditions in that State. In western South Dakota, where the sagebrush is low and can be plowed, it is estimated that the cost of removing it will be much smaller. While sufficient data relating to costs are not yet available to enable a close estimate to be made, it is thought the following statement will cover the cost of preparing land for irrigation:

	Per acre.
Removing sagebrush	$1.00
Plowing	2.00
Harrowing	.50
Grading	.50
Total	4.00

The subject of preparing land for irrigation, construction of small irrigation ditches, and methods of applying water is fully discussed in bulletins of this Department.[a]

OPPORTUNITIES FOR SETTLEMENT.

To the homeseeker of limited means who desires to make a good home, or to the farmer of greater means who wishes to possess an irrigated farm, South Dakota offers large opportunities. The resources of the State are varied, and several years of great prosperity have brought increased capital and population, especially to the eastern portion.

For a period of twenty-five years the Missouri River has stood as a natural barrier to the development of the western half of South Dakota. The great expense necessary to bridge this stream deterred the railroads from effecting a crossing. A large part of this immense area was and still is occupied by Indian reservations. In the rest there were a few scattered ranches where settlers had built log houses and sheds for the protection of their bands of horses and herds of cattle. Only the region adjacent to the Black Hills was farmed on any adequate scale, and this section, being under irrigation, is highly

[a] U. S. Dept. Agr., Office Expt. Stas. Bul. 145; Farmers' Buls. 158 and 263.

developed and prosperous. Because, however, of its isolated situation there has been little communication between this rich and productive section and the eastern part of the State. As a natural result the growth in population and the development in irrigated farming has been quite slow in Butte and adjacent counties until recently.

Within the last two years three railroads have been constructed in the State, west of the Missouri River, as follows: Chicago, Milwaukee and St. Paul Railway from Chamberlain to Rapid City; Chicago and Northwestern from Pierre to Rapid City; and Chicago, Milwaukee and St. Paul from Mobridge, on the Missouri River, westward along the northern boundary of the State. This latter line is being built through to the Pacific coast and traverses part of the northern edge of Butte County. This county is as large as some eastern States, being 150 miles long and 94 miles wide. In June, 1907, there were over 1,000,000 acres of public lands in this county open to entry under the various public-land laws. The county is watered by numerous streams and springs. The soil is rich and quite productive, especially when irrigated. The opportunity for private irrigation enterprises in Butte County will become better as the county becomes settled and cooperation can be resorted to for constructing irrigation works on an adequate scale.

Under the Belle Fourche reclamation project there are a small number of farm units for which water is now available that have not been filed upon, and after the completion of the work there will be several thousand acres of good land open to entry in farms of 40 or 80 acres each, all under water. Work is progressing favorably on this great irrigation project, and there is a splendid opportunity for any who wish to secure a homestead on irrigated land, to do so under this project.

There are other opportunities for settlement on irrigable lands in Fall River County. There are some lands under the Cascade Extension Ditch owned by the company operating the ditch which, under proper cultivation, are very productive. The area of these lands is not great, however, and further extension of irrigation facilities will require the construction of storage dams and reservoirs. Meade County is one of the largest counties in the State and exhibits great variations in altitude, physical features, and soil. There are numerous streams whose valleys offer good irrigation possibilities. The public lands are now being rapidly taken up, but there is an immense area of good land left, offering excellent opportunity for settlement. A large portion of the Belle Fourche project is in this county, and there are several private irrigation works in operation. The country generally in this region has been given over to cattle raising, the natural grasses affording excellent grazing, while the coulees or

draws afford some protection against winter storms. There are several important streams in this county whose flow is now going to waste which could be utilized for irrigating large tracts of land. These streams are of such a character as to require the storage of their flood waters in order to obtain a seasonable supply for irrigation. This will necessitate the formation of associations or companies for undertaking the work on a large scale. Sulphur and Elk creeks would be suitable for such works, since they have a large flood flow, though they are very low in the summer season.

In the western part of the State there is a large area which lies above the stream valleys and beyond the reach of any system of irrigation except that furnished by local reservoirs, built to impound storm waters. This is especially the case in Butte, Meade, and Pennington counties, where there is a large amount of public land. There are hundreds of places adjacent to the Black Hills where such methods of reclamation can be employed with good results, and a small area of land that is now unproductive can be made to yield a good income.

With regard to the class of settlers desired on these lands, it is evident from the foregoing that earnest, hard-working people are the only ones who will succeed on irrigated farms. Intensive farming is hard work and requires industry and close attention to insure success. The results, however, are commensurate with the requirements, so that the successful farmer on irrigated land is sure of rich returns for his labor. The crop is assured, for the water is at hand when needed, and there is no danger from drought. A well-irrigated farm in cultivation is worth $75 to $100 per acre, and the crops produced will undoubtedly pay a handsome interest on this amount. This affords an excellent chance for a settler to secure a good home and pay for it from his crops.

There is nothing mysterious about irrigation, and the process of applying irrigation water to crops can be readily understood by an intelligent farmer. Given a good supply of water, irrigation is simply a matter of applying the right quantity of water at the proper time. Of course experience is necessary to do this, just as experience is necessary to know how to properly perform any kind of farm work. Fortunately, the experience of pioneers and the scientific knowledge of experts can now be taken advantage of by settlers under the Belle Fourche reclamation project. In order that settlers may be properly instructed in the art of irrigation and taught what is necessary in regard to the cultivation and laying out of land so as to insure good crops, the Interior Department is cooperating with the Department of Agriculture. A quarter section of land has been selected by the latter Department as an experiment farm. About one-half of this land will be above the ditch, so that experi-

ments may be made along the lines of both irrigation and dry farming. This will be of great value to settlers, not only to those on irrigated lands, but also to those on higher lands, where complete irrigation can not be effected.

FUTURE DEVELOPMENT IN IRRIGATION FARMING.

A large part of western South Dakota is semiarid. The construction and operation of the private and corporate canals and ditches has resulted in the reclamation of tracts of considerable size. These, together with the reclamation projects now under construction and proposed, combine to make a large acreage of irrigated land. It is believed, however, that irrigation in South Dakota is yet in its infancy. The reclaimed areas, though making a large aggregate, look rather insignificant relative to the rest of this vast region. West of the Missouri River there are large areas still unsettled where streams are available as a source of water supply.

In many localities where irrigation is now carried on there is more water in the stream than is actually needed, and farmers pay little attention to the nature of their right to divert its flow. In other places, as, for example, Rapid Creek Valley, the stream does not carry enough water to supply all the users during certain periods under the crude and wasteful methods practiced. Many of the water rights on this stream have been adjudicated by the courts, and the proportion to which each water user is entitled has been awarded to him. Under the present State water code the regulation of the supply is under the supervision of the water commissioner of the division, who is a State official. This is a guarantee that the water will be fairly distributed, but there is still some danger of a shortage of water at some periods.

CONSERVATION OF WATER.

In the process of irrigation development in semiarid States it is usually found that as the reclaimed areas become larger and the demands upon the sources of water supply increase there comes a time when the matter of securing additional reclamation facilities becomes a very serious question. This has been the experience of every arid State and Territory, and the lessons to be derived therefrom and the remedies to be applied should be carefully considered.

There are various methods employed for obtaining the greatest efficiency from available water supplies, among which the most important are the prevention of waste and the storage of flood waters.

WASTEFUL USE OF WATER.

In all localities where irrigation is practiced there is more or less waste of water. In the canal systems and ditches which supply farms a large proportion of the water flowing through them is lost by absorption and seepage. As water for irrigation becomes more valuable a higher duty will be required, and this can be attained only by making the ditches water-tight by lining the channel with some impervious material such as concrete, plaster, clay, or crude oil.

Greater care will become necessary to prevent the overirrigation of crops, which is a common cause of waste. Many farmers seem to think that because the application of water is beneficial to crops the more water they use the better results they will obtain and proceed to drown their crops with too much water. Others allow the water to run freely without attention, the result being great waste. By the exercise of careful supervision these sources of waste may be eliminated with the result that a much larger area will be irrigated from a given source of water supply.

STORAGE OF FLOOD WATERS.

There are thousands of acres along the streams in the western part of the State that are unproductive because of lack of water. At the same time in all these streams immense volumes of water go to waste during the flood seasons. The obvious remedy for this condition of affairs is the construction and maintenance of large storage reservoirs for holding back this water. The irrigation of 100,000 acres of land is made possible under the Belle Fourche project by storing the flood waters of that stream.

The development of irrigated farming in this State will sooner or later reach a stage where the construction of storage reservoirs on streams will become an important factor. Where the stream is one of considerable size numerous irrigation canals will be constructed from it, and its entire normal flow will then be utilized and means will be provided for holding back the immense volume of water which goes to waste during periods of high water, so as to render it available for use in the drier parts of the year. By such means many large tracts of nonproductive land will be reclaimed.

STORM-WATER IRRIGATION.

Another form of development of irrigated farming is along the line of conservation of storm waters. Irrigation so far has been carried on principally from flowing streams and large natural water supplies, little having been done toward conserving and developing the minor sources of supply. It is not claimed that the development

of the small water supplies will do more than make available a small portion of the higher land away from the large sources of supply. The formation of small reservoirs by building dams across dry draws will make possible the reclamation of many small tracts of land. In the rolling prairie there are very many reservoir sites available, but careful search is necessary to reveal them. A large number of farmers in this region are irrigating by means of storm-water reservoirs tracts of land varying in size from 40 to 200 acres. There are hundreds of places in the country adjacent to the Black Hills where this method could be employed with good results, and the land that would otherwise be without water could be made to produce fine crops.

FOREST CONSERVATION.

An important factor in the public water supply is the conservation of the forests at the headwaters of the streams. The forested areas in the Black Hills act as natural reservoirs to a large extent and add materially to the splendid water resources of that region. The greater part of these areas are now fortunately included in the National Forests and are therefore safe from denudation. The wise policy of the Forest Service will conserve these natural reservoirs, insuring a continuance of the stream flow in this region for all time to come. It is hoped that additional areas among the higher lands comprising the watersheds of other important streams will eventually be forested and thus aid in furnishing a larger and steadier flow of water.

LEGISLATIVE AND OTHER NEEDS.

In order to attain the highest efficiency in irrigation work and at the same time provide for future development, it will be necessary to utilize every available source of water supply to its fullest extent. Reference has already been made to the use of artesian water for irrigation in the southern part of Butte County. It is thought that considerable development will eventually be effected in this manner, although the matter is still in an experimental stage.

While individual effort can accomplish much in the way of reclaiming land by irrigation, it is believed the best results will be obtained by cooperation, as has been practiced in other States. More economical water conservation and distribution can be effected when a number of irrigators obtain their water through one system than by making use of a number of individual systems.

The State water code of South Dakota is based on the experience of older irrigation States in the West, and is in its principal features an excellent law. The provisions relating to the construction of reservoirs, however, are inadequate and require revision. These

allow the construction by individuals or corporations of dams across dry draws or channels where the flow is intermittent without the necessity of a permit from the State engineer, the appropriation being legalized by simply posting a notice on the ground. This method of procedure has already resulted in much dissatisfaction, and the law will doubtless be changed to conform to the public needs.

It is believed that a State law encouraging the storage of water, if enacted in the proper form, will result in the reclamation of many tracts of land that now have an insufficient water supply. Such a law should be so drawn as to interfere in no manner with the State control of diversions, the use of stored water, or its distribution for beneficial use.

A problem that needs investigating is that relating to the limits of State and Federal jurisdiction in the control of streams. Much has been said and written about this question, but it is still unsettled, and serious complications have arisen from the absence of general regulations to govern the division of water across State lines. A concrete instance is that of the Edgemont Reservoir, situated in Wyoming, which has stood idle for years largely because of the question of using the water for irrigating land across the State line in South Dakota.

With regard to interstate streams that are used for irrigation, it is readily seen that the summit States are in a position of advantage over adjacent States of lower altitude in being able to intercept the flow of a stream in its upper reaches; and where a stream flows through several States the same relative conditions hold good. The necessity of a careful and impartial investigation of the matter by competent experts in engineering and agriculture is recognized. No action can be taken by Congress to legislate regarding water rights within States without revolutionizing existing conditions in some of the States and without disturbing vested rights.

It has been suggested that in the case of important streams a commission of experts could determine what proportion of a stream should flow from the upper to the lower State, leaving it to the authorities of the State above to determine what measures shall be taken to accomplish the desired result and to the authorities of the State below to determine what shall be done with the water when received. This would appear to be a good plan, as there would be no interference with vested rights or with State water codes, while at the same time there would be some prospect of securing a fair division of the water supply.

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